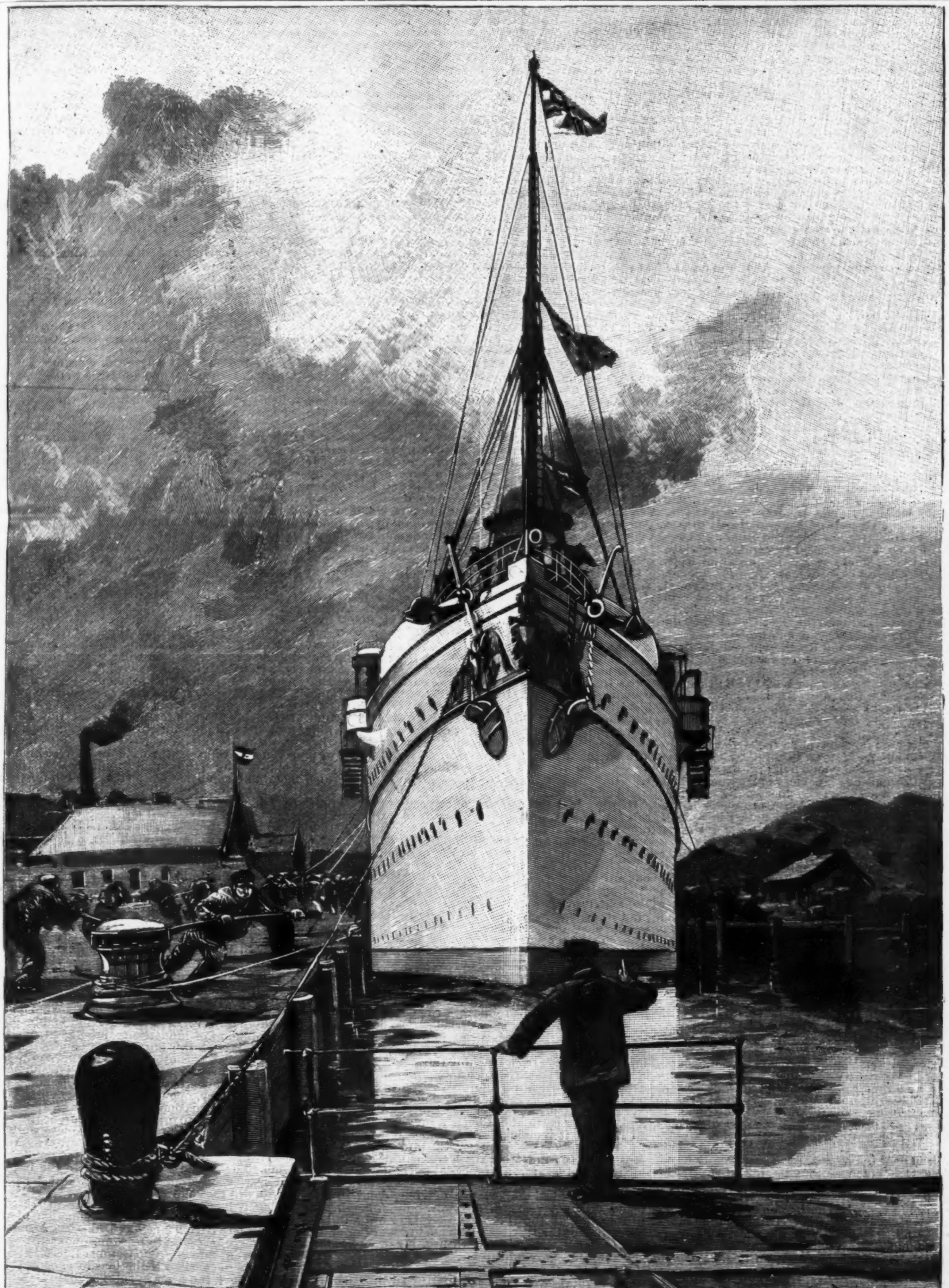
SCIENTIFIC AMERICAN SUPPLEMENT. No 1021

Scientific American Supplement, Vol. XL. No. 1021.
Scientific American, established 1845.

NEW YORK, JULY 27, 1895.

Scientific American Supplement, $5 a year.
Scientific American and Supplement, $7 a year.



OPENING OF THE NORTH SEA CANAL—THE IMPERIAL YACHT HOHENZOLLERN ENTERING THE CANAL.

THE NORTH SEA CANAL.

THE North Sea and Baltic Canal, after eight years of hard work and the expenditure of nearly eight millions sterling, has been completed and opened for traffic, and the Danish peninsula has become an island. The canal, which runs from near Brunsbuttel, in the mouth of the Elbe, to the Fjord of Kiel, on the Baltic, has a length of about sixty miles, a normal width at the surface of 197 ft., a normal width at the bottom of a little over 72 ft. and a depth over the central portion of 29 ft. 6 in., so that the largest vessels in existence, inclusive of all men-of-war, can traverse it without having to lighten themselves, and that vessels not of the largest size can safely pass one another without being obliged to lie up, or even to stop. For the convenience of the very few ships which cannot pass one another in that manner, there are, at intervals, broadenings, or "bays," where the bank to bank width is, for a distance of 820 ft., increased to 328 ft. and the bottom width to 197 ft. Nor are there any overhead obstructions. The canal is crossed by four lines of railway, two of which have comparatively little traffic. For the service of these two swing bridges, pivoted close to the bank, are provided. At ordinary times the bridges are swung round so as to lie parallel with the waterway; and only when trains are due are they thrown across to the opposite side. The whole operation can be accomplished in two minutes. Each bridge is double, a separate swing span carrying each set of rails; and thus, should any unforeseen accident occur to temporarily prevent the working of one span, the entire traffic can be conducted by means of the other. Upon the remaining two railway lines the traffic is heavier, and, in consequence, fixed bridges have been built to carry it. But these bridges are so lofty that no masted ship now afloat need, before attempting to pass under them, send down more than her topgallant masts, which are spars such as, of course, she would not need in a canal in any conceivable circumstances. The height between water surface and bridge is within a few inches of 138 ft. and the spans, which are the broadest in Germany, have a reach of 511 ft. A third swing bridge, at Rendsburg, is for the use of vehicles and foot passengers.

The new canal is not lockless, although it is nearly so. The Baltic Sea is almost without tides; and, therefore, a lock at the Baltic end is rendered necessary only by the possibility that occasionally a strong northeasterly gale may pile up the water to an inconvenient extent in Kiel Bay. The effect of the eastern lock, when closed, will be to prevent a special tide of that kind from flooding the banks of the canal; but ordinarily that lock will be left open throughout the twenty-four hours. At the Elbe, or western end, the situation is different. There the rise and fall are considerable, and consequently, at every ebb, in order to maintain the desired depth of water the gates must be closed for some hours, though ships will still be able to pass through, subject to the delays which are attendant upon the passage of all locked canals. The two terminal locks are very important engineering works. Each really consists of a pair of locks, placed side by side, and parallel one with the other; and the dimensions of each lock are: clear length 492 ft.; width 82 ft.; depth 32 ft. There are, so far, no ships 82 ft. broad; but there are a few ships more than 492 ft. long. Even these monsters, however, can traverse the canal whenever it is not necessary to use the locks, or, in other words, during by far the greater portion of every day. Indeed, compared with the Suez Canal, the new waterway may be regarded as a fine broad highroad, whereas the older work is but a well-kept country lane. There are many ships that cannot use the one; there are none that cannot use the other.

The advantages to the commerce of the Baltic must be considerable. On the route from London to St. Petersburg the canal saves 238 miles; on the route from Hamburg to St. Petersburg it saves 424 miles; and, since it has been estimated that there are now annually about 1,500 ships having a registered tonnage of 1,100,000, which might greatly gain by using the canal, it is clear that the commercial prospects of the enterprise are promising. In fact, much more than half of the whole Baltic trade is expected by sanguine authorities to adopt the new route, especially if the present very moderate rate of tolls be not increased. It is probable that the canal will be frozen during at least a month every winter; but the ice obstructing the natural entrance to the Baltic often exists for a far longer period, owing to the comparative freshness of Baltic water. Recent observations show that already the canal water is salter than the water in Kiel Fjord; so that apparently a greater difficulty may next winter be experienced in approaching the canal than in traversing it. But, apart from this, it must always be more easy to make effective use of ice breakers in the canal than in the open sea, and, aware of this, the administration has secured a very powerful ice-breaking plant, with the assistance of which it does not despair of keeping the way altogether open during all but the severest seasons.

The quantity of traffic that can be dealt with is almost unlimited. Work may go on night and day, seeing that the canal is lighted electrically from end to end, that there are plenty of powerful tugs at the disposal of the administration, that at each end there are capacious basins in which vessels may await, if necessary, their turns, and that a speed of 5·3 knots, or upward of six statute miles an hour, will be permitted even to merchantmen using the route. Warships will, of course, adopt such speed as service considerations may render desirable or possible; and with a view to this sort of express traffic, the banks of the canal, along the greater part of the length, have been solidly faced, so as to resist, as much as may be, the disruptive effects of the wash of heavy ships passing rapidly. A local engineer tells me, however, that he doubts whether any big vessel, no matter how powerfully engined, could steam at more than ten knots in the canal, the water being so shallow, and the inevitable result of the attempted rapid motion of a 10,000 ton craft in such a narrow channel being to push a huge volume of water in advance of her, and so to create enormous resistance. But I need not, after all that has of late been written on the subject, dwell further either upon the construction of the canal or upon its commercial future. Other matters claim attention.

One aspect of the importance of the North Sea and Baltic Canal has certainly not yet received the attention which it merits; and that aspect is the strategical one. The commercial advantages of the work are sufficiently patent to be easily distinguished by all; but it would be a mistake to imagine that the practical German government has been induced merely, or even mainly, by commercial considerations to spend its millions on the new waterway. If commercial considerations had been the only ones to be kept in view, nothing is more certain than that the whole affair would have been left to private initiative, and that the imperial government would have vouchsafed very little material support to the venture. But, in fact, commercial considerations are very subsidiary ones in comparison with the strategic gains which the rulers of the new German empire have sought for and have at length attained. In order to fully understand what these are, one must briefly survey the strategical situation from the naval point of view of some European countries which, up to the present moment, have shared with Germany the peculiar disadvantages from the influence of which she has now relieved herself.

These countries are France and Russia. Each of them, like Germany, has hitherto possessed a divided naval force, capable of concentration only with the assent, or, failing that, in the event of the inability to prevent it, of certain other powers. The whole force of France at sea may be accepted as about equal to three times the whole naval force of Germany, or as about equal to twice the whole naval force of Russia. This being so, the relative naval strength of the three great military powers of Europe, as estimated by the amount of materiel belonging to each, may be roughly expressed by the following figures: France, 60; Russia, 30; Germany, 20. The accuracy is at least amply sufficient for purposes of illustration. France normally maintains about two-thirds of her naval force in, or dependent on, the Mediterranean, and one-third in, or dependent on, the Atlantic ports on her seaboard; so that her Mediterranean strength is represented by 40, and her Atlantic strength by 20. She ought not to be able—I fear that I dare not say that it is impossible for her—to effect a junction of the two divisions so long as we hold an interior position in or near the Strait of Gibraltar, and desire to prevent the operation, or so long as she has to keep in check a large Italian fleet, based upon Spezia, Naples and Taranto. Therefore, her relative force, available for operations in the North Sea or Baltic, need not be estimated as superior to the entire naval force of Germany. Russia is similarly situated astride the continent. In the Baltic, she has about two-thirds of her strength; in the Black Sea, about one-third; and she cannot hope to assemble the two divisions anywhere without the acquiescence of Europe. Thus France and Russia are each, so far as the North Sea and Baltic are concerned, about equal to Germany, but not more than equal. Each can bring against her a force expressed by 20; and she, in return, can oppose a force expressed by 20. Until now, Germany, like France and Russia, has had the solid land between the two divisions of her fleet, and has only been in a position to combine the two portions subject to the good will or to the impotency of the powers holding the roundabout sea routes, by which alone these two portions could reach each other.

One division, valued at 10, had its headquarters at Wilhelmshaven, where it was subject to observation, if not blockade, by a French force valued at 20; the other, also valued at 10, had its headquarters at Kiel, where it was subject to observation or blockade by a Russian force valued at 20. Even if Russia were not hostile, there would still be risk of a French force, valued at 20, taking up such a position off the Scaw as to be able to prevent the Kiel and Wilhelmshaven forces from joining, and to defeat each in detail, should it venture out. But the North Sea and Baltic Canal has altered all that. Whereas formerly Germany could not hope to meet either France or Russia upon equal terms, she may now feel pretty confident of being able to oppose equal forces to either. Moreover, she has secured for herself the interior position. The way, by sea, from the mouth of the Elbe, at Brunsbuttel, to Kiel Bay, in the Baltic, occupies about 62 hours, at a speed of 10 knots.

By the canal the passage, at a speed of only 5 knots, can be made in 12 hours; so that henceforth the two divisions of the German fleet can unite in less than one-fifth of the time needed for the union of hostile forces, observing the Elbe, on the one hand, and Kiel on the other; and, in addition, they can unite without any possible interference on the part of the foe. It is not too much to say, then, that the existence of the canal doubles the strategical strength of the German navy, so far, at least, as it may be called for for employment either in the North Sea or in the Baltic. The cost has been, roughly, £7,800,000. To have actually doubled the German fleet would have cost, at the lowest computation, £14,000,000.

It is true that the canal although it has been spoken of as uniting Kiel and Wilhelmshaven, does not literally unite them; for Wilhelmshaven is not in the mouth of the Elbe, but some miles to the southwest, in the estuary of the Jade. Nevertheless, no hostile fleet, in time of war, when beacons and lightships would, of course, be removed, could hope to prevent the Germans in the Elbe from reaching the Jade at their pleasure. The two estuaries blend together into a larger estuary, which is, over the greater part of its extent, a network of difficult channels among sandbanks, a few miles outside of which lies Heligoland. That island, since its cession, has been strongly fortified, and, so long as it remains German and is not swept away by the storms of the North Sea, the interior water space must, at least while there is a German fleet in being, be regarded as, for all practical purposes, a German roadstead.

The strategical importance of Heligoland to Germany was not realized, and was, indeed, laughed at in England at the time of the cession; but a full appreciation of the services to which, in case of need, the Baltic Canal is to be put throws a new light upon the subject, and vindicates the carefulness and foresight of the German government. An English Heligoland might have gone far toward entirely neutralizing the value of the canal; a German Heligoland gives it a singular completeness.—W. Laird Clowes, in the Nineteenth Century.

[FROM THE ENGINEER, LONDON.]

THE TIN PLATE INDUSTRY IN THE UNITED STATES.*

IN regard to the questions of price and consumption of tin plate, it is thought that the present price will decline considerably, perhaps as much as 25 per cent., but that this will result in an increased consumption, new uses being found for the cheapened material, as, for instance, in packing many articles of food now packed in wood or glass. A reduction in price, however, would almost certainly be accompanied by a corresponding reduction in wages to reduce the cost of manufacture.

As to the financial results, it is certain that the most successful manufacturers will be those who can get the cost of production down to the minimum without impairing the quality of the product. The manager of one of the large works states that with careful and economical management and a full product of the plant, there should be a fair, legitimate profit even at present prices, but that the erroneous idea that the business is a veritable gold mine will be dispelled before many of the new works have been running for a year. He considers that a carefully conducted plant ought to net about 20c.—10d.—per box, but that a much higher figure cannot be reasonably or safely estimated.

Another matter which I have made the subject of inquiry is the employment of Welsh workmen, and the results show a very decided diversity of opinion. One company which is making extensive enlargements of its works writes as follows:

"Regarding the nationality of employes, doubtless, many of them will be Welsh. This question, however, is never taken into account, and we would as soon have a good American as the most expert Welshman, for we find the American workmen fully as capable in anything they undertake to do."

Another firm, which does not roll its own black plates, says:

"We are entirely independent of Welsh workers, and have none in our factory."

Two other firms say that they do not find it necessary to employ Welsh workers in any of their departments, and still another firm, commenting on this matter, say that labor saving machinery does away with much skilled labor, and, of course, Welshmen are not needed as unskilled laborers. One of the large companies writes as follows:

"We find our most successful workmen to be young Americans who have had some experience in rolling mill work, and that these, when properly directed, very quickly equal, if they do not excel, the Welsh workers we have employed."

On the other hand, another large company writes as follows, but evidently makes its statements too broad in regard to other manufacturers, as will be seen by comparing the following remarks with those preceding:

"In answer to your inquiry as to whether we find it necessary to employ Welsh workers in all the departments of our plant, we will say that we do, and so will any American manufacturer. If you will stop a moment and consider the matter, you will readily understand that the tinplate industry is a new one in this country, and that the American workmen have to learn it in all its branches. For this reason it is necessary to have Welsh workmen here to teach the Americans how to make tin plate. When the silk industry was introduced into America from France, French workmen were brought to this country to instruct American workmen and teach them the business. And still further back Frenchmen went to China and learned the business there. So you will see that any new industry started in any country will have to be learned at first from experienced workmen in that business."

The above does not sound very convincing, and the industry certainly seems to be old enough to no longer be dependent upon foreign workers, and this view appears to be borne out by the other statements quoted. In regard to these diverse views I give the following communication sent to me by a Welshman in this country who is thoroughly familiar with the development and condition of the American industry:

"As to the advisability or necessity of employing Welsh workers, I am not surprised to learn that in this connection you find a diversity of opinion among the manufacturers. This difference of opinion is due more to the conduct of those Welsh workers who have already come to this country and are employed at the tin plate works than to any other reason. There is no question as to their ability, and, of course, for the time being their superiority as skilled workmen in this branch. A large number of American workmen employed in the tin works have already become skilled workmen, who are in every respect equal to, and in some cases superior to, the Welsh workers. Every little labor difficulty we have had in the tin plate works in this country thus far has been brought about by the foreigners; and I regret to say—particularly for the reason that I am a Welshman by birth myself—that the conduct of these men has been most arbitrary, and their arrogance beyond endurance. There is, however, a wide field for employment to a large number of industrious, intelligent Welsh workers in this country; but I do not believe it is advisable to offer much encouragement to the Welsh workman leaving Wales for this country. The higher wages paid, and the better environments of skilled workmen in this country, ought to be sufficient inducement to any foreigner to come to this country, and it has been our policy not to give any encouragement—in any direction whatever—to Welsh tin plate workers coming to this country. I beg to assure you that—as I have already stated—the diversity of opinion existing among our people is chiefly due to the insolent and arbitrary conduct of such Welsh workers as we have already in the country."

The reduction in price and the increased foreign competition resulting from the reduction of the duty on tin plate from 2·2 cents—1 1d.—to 1·2 cents—0·6d.—per pound, or \$20—£4—per ton, under the new tariff, which went into effect on October 1, 1894, led the manufacturers to consider reductions in expenses. In September, 1894, the firms in the Tin Plate Manufacturers' Association proposed to the labor organizations in

* Continued from SUPPLEMENT, No. 1020, page 16301.

which the iron and steel workers or black mill men were enrolled a reduction of 30 per cent. in wages of rollers, 25 per cent. for heaters and about 20 per cent. for the other branches of labor. The men in the organization refused to accept the reductions and serious labor troubles began. Several mills were shut down, while others—mainly those in the natural gas belt of Indiana—continued with non-union labor, working more or less under difficulties from the hostility of the union men. After several conferences between the representatives of the manufacturers and the representatives of the labor organization, a compromise scale was agreed upon in January, and is to continue in force until June 30, 1895, when the question will again be taken up. Under this compromise scale the men agreed to reductions of 15 per cent. in wages for the rollers and 12½ per cent. in wages for the doublers, heaters and shearers, these reductions being for the No. 29 and No. 30 gages upon which the wages are based, while for gages No. 27 and No. 28 the reductions were 12½ and 10 per cent. A number of firms accepted the compromise and signed the scale. Under the old and new scales the wages per ton of 2,240 pounds are as shown by table No. 6, gages No. 29 and No. 30 being taken as the basis, and the wages getting lower with the smaller numbers and higher with the larger numbers of gage, the limits in each case being shown by the table. The "extras" quoted are unchanged, remaining as under the old scale.

TABLE NO. 6.—WAGES IN AMERICAN TIN PLATE MILLS.

Men.	Gages. No. 22 and 30. Dols. s. d.	Gages. No. 8 to 11. Dols. s. d.	Gages. No. 38. Dols. s. d.
New scale:			
Rollers	4.50 = 18 9	2.04 = 4 4	6.46 = 21 1
Doublers	2.36 = 9 10	.93 = 3 10	3.26 = 13 7
Heaters	2.17 = 9 0	.85 = 3 6	3.13 = 13 0
Shearers	1.54 = 6 5	.99 = 4 1	2.21 = 9 3
Old scale:			
Rollers	5.30 = 22 1	2.04 = 4 4	7.60 = 30 10
Doublers	2.70 = 11 3	.93 = 3 10	3.72 = 15 6
Heaters	2.48 = 10 4	.85 = 3 6	3.58 = 14 11
Shearers	1.76 = 7 8	.99 = 4 1	2.52 = 10 6

NOTE.—(1) The above prices are for steel plate, and for iron plate the wages are 13 per cent. less, except for the shearers.

(2) The above prices for shearers are for shearing on jaw or crocodile shears and job-work on squaring shears. Shearers on modern squaring shears receive $1—4s. 2d—per turn, but for gage No. 25 and lighter gages 87½ cents—3s. 7d.—per turn is paid. This clause applies only to shearing tin plate.

Extras.—(3) Twenty per cent. added for changed steel and 20 per cent. on net price of iron.

(4) Seventeen per cent. added for pickle finished iron and steel, except shearer.

(5) For all sheets sheared into circles in tin and black plate mills where the loss exceeds 10 per cent., 20 per cent. extra is paid.

(6) All sheets cut down to smaller sizes in tin and black plate mills are paid for at scale prices.

In regard to this question of wages the president of one of the largest tin plate manufacturing companies in the United States said that the passage of the new tariff bill of 1894 compelled his company to make a reduction in the wages of the rollers, doublers and heaters. Under the tariff of 1891 the company paid these men wages 150 per cent. higher than wages for the same work in Wales, and even under the new tariff it paid wages 100 per cent. higher than in Wales.

The reductions above noted apply only to the men in the black plate mills. The wages in the tinning departments differ at the various works. In the tinning and finishing departments on Morewood sets at some works the tinman and washman are paid 12 cents—6d. —per box, and at others 11 cents—5½d.—per box. The riser is paid 4 cents—2d.—per box and the assorter 3½ to 4 cents—1¾d. to 2d.—per box. On patent machines the work is usually done by the day, and dippers get from $2 to $2.50—8s. 4d. to 10s. 5d.—per day; risers $1.50—6s. 3d.—per day, and assorters about 3 cents —1½d.—per box.

Practically all the black plate is of Bessemer steel; but the use of open hearth steel has been advocated for certain purposes, especially for plate for deep stamping. The main difficulty in operating an open hearth steel plant in connection with a tin plate plant is, that the steel plant can hardly be economical with a capacity of less than 150 to 200 tons per day, as it is necessary to keep the blooming mill constantly employed. As the largest tin plate works would not require more than 125 tons of steel per day, the open hearth plant is out of the question unless its product is sold in the steel market, or unless several tin plate works combine to operate the steel plant. At present this class of steel is consumed mainly by its makers, and very little is sold in the open market, and the price is too high to make it available for tin plate works. As an alternative it is suggested that an open hearth plant could be operated with a fair degree of economy by casting only small ingots, of a size suitable for the bar mill with which all large plants are equipped; and while the economy would be less than with the large plant, it is said that the cost of the steel would be decidedly less than if purchased in the open market. A good grade of steel for plates from which stamped articles are to be manufactured has a composition as follows: Carbon, 0·08 to 0·01 per cent.; sulphur, below 0·05; phosphorus, below 0·02; manganese 0·25 to 0·35; silicon, a trace only. It is said by a steel maker, however, that much tin plate, stamped ware, etc., is made from steel containing 0·08 to 0·12 per cent. of phosphorus.

Among the best equipped tin plate plants in this country is that of the Irondale Works, occupying a site of eight acres adjoining the P. C. C. and St. L. Railway, from which side tracks are laid to the mill. A sketch plan of the plant is shown in Fig. 2. There are six hot mills and six cold mills, together with the necessary doubling and squaring shears, heating furnaces, annealing furnaces, picklers, and a tin house with eight tinning sets.

Only three of these sets are running at present, for the reason that the company secured a very large order for black plates when it first went into operation, and therefore needed only to make its tinning capacity equal to the surplus of black plate that it turned out. The general arrangement of the plant is in the form of a U, and the raw material comes in on one side, moves gradually round from stage to stage of its manufacture, and is shipped as completed product on the other side. The main building of the rolling mill is a steel structure 200 ft. long and 150 ft. wide.

Four of the hot mills run across this building, and are driven by one of Totten and Hogg's "Ætna" engines, of 600 horse power, with cylinders 26 in. by 48 in., the engine being in the middle, with two mills on either side. Steam is supplied by a battery of five tubular boilers, each 5½ ft. diameter and 16 ft. to 18 ft. long. The other two hot mills and the six cold mills are placed in line lengthwise of the building, all being driven by a 600 horse power engine with Corliss valves, supplied by another battery of five boilers, similar to the above. These hot mills are said to be among the heaviest ever used in tin plate work, the rolls being 24 in. diameter, with 19 in. necks, and the housings weighing 22,000 lb. each. There are three squaring shears to take care of the output of all six mills. The Gray pickling machine is of the most improved pattern, improved upon the Welsh machine, and has a capacity of 1,000 boxes per day. The two annealing furnaces have capacities of 30 tons and 20 tons respectively. The tinning sets have Thomas and White pots. The cold rolls are to be put in a separate building and driven by a separate engine, their places being taken by two more hot mills. The object of this is to remove the cold rolls away from the particles of dust, dirt, cinder, scale and sand that are always flying about more or less in a rolling mill, and which have a tendency to destroy the finish of the plate. The plan also enables the cold rolls to be run independently, which is at times a considerable advantage.

The general manager, Mr. Jackson, says that the capacity of the six mill plant is about 10,000 tons per annum. Good mill practice would require that there should be a loss of not over 20 per cent. from the steel bar to the finished black plate ready for the tinning pot, including both picklings. About 12 to 15 per cent. of the loss is at the squaring and doubling shears, and if the steel is properly rolled the loss of weight through both picklings and the annealing should not exceed 3 per cent. In using acid of 60° B., the two picklings should be done with not more than 5 lb. of acid to 100 lb. of steel. The output of two mills for one week was 155,455 lb. of black iron and 24,617 lb. of white iron, making a total of 180,072 lb., for which 8,716 lb. of acid were used, or 4⅘ lb. of acid per 100 lb. of steel. These results have only been attained by a great deal of attention, and probably there are more mills using 8 lb. to 12 lb. than using less than 8 lb. of acid.

There should be no apparent loss in the steel in passing through the furnaces if the bars are properly boshed. The principal feature is to obtain a good quality of black plate, as with this good tinned plate

FIG. 2 PLAN OF TIN-PLATE MILL

can be made with a minimum of wasters, the tinning process not being intricate. The tinning sets produce fifty boxes per turn of ten hours, on a basis of 112 sheets of 14 in. by 20 in. plates to the box. In making the I. C. cokes standard quality, the aim is to produce a marketable plate, fully up to the standard, at not more than 2 lb. and 4 oz. or 5 oz. of metal. Pyrometers are used at the tin pots to enable a uniform temperature of the grease and metal to be maintained. Experience has shown that there is no money to be saved by buying an inferior grade of palm oil. The branning and polishing will be done by machines when the tin house is finished, but at the present time this work is done by hand, as in view of the experimental work, and the constant improvement of such machines, it is considered desirable to delay purchasing until such times as machines are absolutely needed. The endeavor is made not to exceed 5 per cent. of wasters in the tin house, and whenever this is exceeded, an investigation is at once instituted as to the cause.

The Newcastle Works include a mill building 250 ft. by 110 ft., with steel columns 24 ft. high, corrugated iron sides, and a floor of brick and cast iron plates; the pickling, annealing, and tinning plant is in a brick building 362 ft. by 60 ft. and there is a machine shop 70 ft. by 60 ft. The rolling mill has six mills, with hot and cold rolls 22 in., 23 in. and 24 in. in diameter, driven by an engine with a cylinder 30 in. by 60 in. and having a 40 ton fly wheel. This present plant has a capacity of 35 to 40 tons of black plates per day; but it has been decided to extend the works, and put in ten or twelve more mills, so that the enlarged plant will have a capacity of 100 to 125 tons of black plates per day, making this one of the largest, if not the largest, single plant in existence. The additions are to be put in this season, and the contracts have been placed. The two new buildings will be 360 ft. by 110 ft. and 360 by 105 ft. with steel columns and roof trusses and corrugated iron sides, and the machinery will be arranged with a view to the greatest facilities in operation and in handling the material. The hot rolls will be run by two Bass-Corliss engines of 1,100 horse power each and the cold rolls by one Bass-Corliss engine of 700 horse power. A specially notable feature is that the usual gearing will be dispensed with, and the mills operated by rope drives, there being twenty-eight ropes 2 in. diameter, running on wheels 25 ft. and 14½ ft. diameter. An electric light plant will be put in supplying 100 arc lights of 2,000 candle power for the mill and incandescent lights for the offices. Electric cranes will be used in the hot mills and cold mills and in the annealing department. The new machinery will include the latest improvements and labor-saving appliances.

The Meurer Works have increased their capacity from 800,000 lb. to 1,000,000 lb. per month. The additional building is 95 ft. by 50 ft. with steel columns and roof trusses, brick walls, and corrugated iron roof with skylights. The floor is of concrete. The new equipment includes six Phillips' tinning pots, furnaces, etc.

The Crescent Works, recently completed, are laid out for twelve mills, but work commenced in May with four hot mills having a capacity of about 7,000 tons per annum. The tinning plant will be put in operation during the summer. The mill building will be 105 ft. by 175 ft., the tin house 105 by 168 ft. and the annealing house—containing also the pickling machines—48 ft. by 48 ft. The rolls will be driven by two engines with cylinders 34 in. by 72 in. There will be two electric traveling cranes of 10 tons capacity, and an electric light plant supplying fifteen arc and sixty incandescent lamps.

The Laughlin Works, now under construction, will rank among the largest. The hot mill building will be 70 ft. by 140 ft., with sides 20 ft. high, and having a shed roof 20 ft. by 140 ft. covering the heating furnaces and a shed roof 25 ft. by 140 ft. covering the annealing furnaces. The cold mill building will be 62 ft. by 140 ft., with sides 24 ft. high, and having a shed roof 25 ft. by 80 ft. over the annealing furnaces. Both these buildings will have traveling cranes. There will also be a boiler house, 40 ft. by 88 ft.; tinning house, 60 ft. by 75 ft.; and packing house, 60 ft. by 50 ft. The hot mill will have ten sets of 24 in. rolls—commencing with six sets—and the cold roll mill seven sets of 20 in. rolls —commencing with four sets. The machinery will include an Ætna engine of 1,000 horse power for the hot mill, a 700 horse power Ætna engine for the cold mill, an engine of 100 horse power for the doubling and trimming shears, and another of 75 horse power for the tinning house. There will be 8 tinning machines—six Thomas and White, one Morewood, and one Phillips—a single and a double dusting machine, and one Gray pickling machine; also sixty annealing boxes, feed water heaters, pumps, ten boilers of 100 horse power, and the usual equipment of shafting, pulleys, etc.

A number of new works have been put in operation during the past few months, including the following:

Great Western.—Four heating furnaces, two hot roll trains, one cold roll train, with an annual capacity of 4,500 tons of black plates. Three tin plate sets and three terne plate sets in operation, with weekly capacity for 1,500 boxes of 14 in. by 20 in. tin plates, and 750 boxes of 20 in. by 28 in. terne plates.

Reading.—One tin plate set and one terne plate set, each with a capacity of 250 boxes of 14 in. by 20 in. plates per week.

Ætna.—Eight hot mills in four trains, and three cold mills in three trains, with an annual capacity of 12,000 tons of black plate. Six tin plate sets and two terne plate sets, with capacities of 4,000 boxes of 14 in. by 20 in. and 750 boxes of 20 in. by 28 in. per week respectively.

Morton.—Six heating furnaces, two annealing furnaces, one hot mill train with three stands of 24 in. by 32 in. rolls, one cold mill train with three stands of 20 in. by 32 in. rolls; annual capacity 5,250 tons of black plates. One tin plating set and one terne plating set with weekly capacity for 500 boxes of 14 in. by 20 in. tin plates, and 500 boxes of 14 in. by 20 in. terne plates.

Pittsburg.—Four heating furnaces, two hot mills, and three cold mills; annual capacity 3,750 tons of black plate. Five sets turning out 1,500 boxes of 14 in. by 20 in. tin plates and three sets turning out 900 boxes of 14 in. by 20 in. terne plates per week.

Monongahela.—Nine heating furnaces, nine hot mills, and six cold mills; annual capacity, 20,000 tons of black plate.

Atlanta.—Four heating furnaces, two hot mills, and three cold mills; four tin plate sets and three terne plate sets, each of 3,000 boxes of 14 in. by 20 in. plates weekly capacity.

Beaver.—Eight heating furnaces, four hot mills, and four cold mills, with an annual capacity of 6,000 gross tons of black plate; six tin plate sets with weekly capacity of 350 boxes, 14 in. by 20 in.; and two terne plate sets with capacity of 150 boxes 28 in. by 20 in.

The above are but a few examples of the numerous works recently added to the list of works in operation, and besides these there are a number of works in various stages of construction, while new companies are being organized and new projects reported continually. In addition to the many new works being established, many of the existing works are making extensive additions to their plant, and among the encouraging features of the outlook for the future of this industry are the large business in tin plate machinery, the improvements in such machinery, and the introduction of labor-saving apparatus. This latter enables an economy to be effected by reducing the number of and the pay roll for the workmen required for a given output, and while this is perhaps not very encouraging from the workmen's point of view, it is a necessary result of the exigencies of close competition and labor troubles. Thus, one firm which has been in operation since June, 1893, has never done any hand dipping, but with four machines has a capacity of 800 boxes of plates 14 in. by 20 in. per week of sixty hours. The only skilled workman employed at this plant is the foreman, and he is able to instruct all new hands to work the machines in a short time. The introduction of labor-saving devices and machinery is a marked feature in the development of many branches of industry in the United States. Such devices are of less importance in England, where wages are so low, but one manufacturer points out that even there they are a matter for consideration, as if 25 or 50 cents—1s. or 2s.—per ton can be saved in the rehandling of material in a year, it would amount to a considerable item.

(To be continued.)

EXPERIMENTS WITH LIQUID GAS ENRICHERS.*

By T. STENHOUSE, F.I.C., F.C.S.

DURING the last few years many gas managers, instead of using cannel coal, have raised the quality of the gas obtained from ordinary coal to the required standard by using liquid enrichers. These have been vaporized by steam in various kinds of carburetors. Generally the gas is improved two or three candles in

* From the Journal of the Society of Chemical Industry.

this way. There is, however, a great difference in the few published statements respecting the value of the various hydrocarbons commonly in use—especially of carburine and benzol. Probably there is as great a difference between the privately circulated results believed to have been obtained at various gas works where enrichers of this class are employed. Dr. Bunte, for instance, makes the rather wide statement that between 7 and 9 grains of benzol vapor will improve 1 cubic foot of gas between 4 and 5 candles.

This is equal to an improvement of 1 candle in over 30,000 ft. of gas by 1 gal. of benzol.

In a letter to the Journal of Gas Lighting (February 19, 1895), Mr. Hunt, of Birmingham, stated that 1 gal. of benzol enriches 9,500 ft. 1 candle, and that 1 gal. of carburine improves 2,800 ft. to the same extent.

In an interview with Mr. Wm. Young, of Peebles, a report of which occurs in the Gas World for January 26, 1895, this gentleman credited a gallon of benzol with an enrichment value of only 4,500 candles, and carburine with being only one-fourth as effective. These statements are so greatly at variance that a gas manager, wishing to select some enricher of this kind for his gas, must be not a little perplexed and scarcely able to calculate what the cost will be.

Of course, it is quite possible that gases of the same illuminating power may so differ in composition that no particular enricher will have exactly the same improvement effect upon them. This, however, cannot account for the enormous differences just noticed.

With a vew of ascertaining the relative values of a few enrichers for coal gas, I have recently made some careful experiments with several liquids, but principally with carburine of 0·680 sp. gr., and commercially pure benzol. The gas used was of about 16 candle power and was improved from 1 to 2 candles. The photometer employed was the ordinary 60 in. open bar photometer at the Rochdale gas works. A Methven 2 candle screen replaced the candles, so as to avoid any trouble with the latter during the tests. The gas, after leaving the meter, was by-passed through two flasks with short lengths of glass tubing. The first flask it entered was a small one, holding a quarter of a liter, the other had a capacity of two liters. The inlet tube reached nearly to the bottom of the small flask, while the outlet tube only just passed through the cork. The tube arrangement was reversed in the larger flask—the gas entering at the top and leaving at the bottom. The lower part of the small flask was heated on a water bath, and the liquid enricher allowed to fall in drop by drop. In this way the gas was enriched each time a drop entered and became volatilized, but as the gas immediately passed into and became diffused through the larger flask, there were only very slight variations in the illuminating power of the improved gas when the enricher was added uniformly for about 15 minutes. With a few trials it was soon ascertained at what rate the liquid, whatever it was, must be added to give one or two candles enrichment and allow accurate readings to be taken at the photometer. The liquid enricher was measured from a burette with glass tap, and passed into the flask at the required rate. After the gas had been improved to a suitable extent and was burning at the proper rate, the liquid in the burette was carefully read off, and a test, lasting say half an hour, was made.

With an arrangement of this kind it is not at all difficult to watch the photometer disk and regulate the supply of the enricher, so that the illuminating power of the gas shall remain fairly steady at one value, say at 18 or 19 candles as may be required. Certainly the difference between the readings is not greater than what is experienced when using candles in the ordinary way while testing unenriched gas. With the addition of one drop of benzol from the burette about every 20 seconds, one can get an improvement of about 2 candles when the gas is burning at 5 cub. ft. per hour. Between two and three times as much carburine is required to give the same improvement.

Added in this way practically all the liquid is vaporized under the influence of heat and the stream of gas playing over the bottom of the small flask. Even with enrichers containing small quantities of dense hydrocarbons, there is a mere stain left in the flask after an hour's test. Under these circumstances one may safely rely on obtaining the full duty from the liquid under examination, as it is practically all turned into vapor and carried directly into the flame, the illuminating power of which is being determined. As the flame is never more than equal to 18 or 19 candles in these tests, the gas is never saturated with the added vapor, and consequently will have no tendency to deposit anything either in the larger flask or in the short length of tubing leading to the Argand burner. It may here be remarked that at Rochdale, where carburine has been employed as an enricher during the last two or three years, Mr. T. Banbury Ball, engineer and manager of the gas works, has not found that any of the liquid has condensed in any of the siphon boxes attached to the mains, notwithstanding the severe frost of last winter.

Working in the way just described, the following results have been obtained with the respective liquids:

	Gas enriched 1 Candle by 1 Gallon of the Liquid. Feet.
Benzol (chemically pure)	13,300
Benzol (90)	12,500
Carburine (0·680 sp. gr.)	5,700
Common petroleum spirit of 0·700 sp. gr.	4,300

Of these liquids, the two important ones are commercially pure benzol and carburine or light petroleum spirit. Their composition is well understood. As the specific gravity shows, a gallon of the former contains about 2 lb. more real matter than the latter. Besides that, the molecular structure of the benzol molecule is such that, of all the liquid hydrocarbons known, it is the one which may be expected to break up most readily into that wonderful acetylene of which we have heard so much lately, and which, according to some authorities, puts everything else in the shade as a light producer.

Benzol is a liquid which is being produced more plentifully every year from the gas and tar obtained from coke ovens. It was recently estimated that 50,000,000 gals. of benzol could be obtained from the 30,000,000 tons of coal annually coked in Great Britain, if the coking were done in closed ovens. There is, therefore, every probability that this most useful liquid will be available in the near future in greater quantities. It is already a rival of carburine, and may soon supersede it altogether for enriching ordinary gas of 15 or 16 candle power. So long as benzol can be purchased at 1s. per gal., it is, in my opinion, decidedly preferable to carburine, even at the lowest price at which the latter has yet been sold. Volume for volume it is about 2¼ times as efficient as a gas enricher, and there is less loss and danger from evaporation during transit. The temperature at which benzol volatilizes is also a convenient one, as ordinary steam heat is all that is required. The amount of benzol vapor which common coal gas can permanently retain, viz., over 50 grains per cubic foot at 0° C., is greater by far than anything required to enrich low quality gas to any reasonable extent. If used in a rational way, there is therefore no need to fear that the added benzol will be condensed and deposited in the gas mains.

A FOLDING CAMERA.

MANY have doubtless begun work in photography as I did, with a very cheap affair made of tin, a small plano-convex lens and the plate holder forming back of box, so a person would have to carry a dark room with him in order to change plates or else be satisfied with one negative a day while out on a tramp.

Besides being limited in capacity it was inconvenient to carry, so I planned a folding camera, using the same lens but following suggestions given in the SCIENTIFIC AMERICAN for making plate holders. Now camera and several plates may be carried in the pockets and the tripod used as a staff. The entire weight, including half a dozen loaded plate holders, is 2½ pounds.

The lens, A (Fig. 1), mounted complete can be purchased for twenty-five cents, is about 3½ inch focus and will cover a 3¼ × 4¼ plate, the size I now use.

The outside dimensions of box are 5½ × 4½ × 3¼ inches, but can be made less by using thinner wood and changing the interior construction somewhat.

The front board, when extended, is retained in place by pins on inside edge of flaps, B, which in turn are secured by hooks, C.

When folded, the flaps, which are pivoted at the corner plates, D, are held down by the clip springs, E, making the box 1¾ inches deep.

The flange, F, is for receiving the mouth of the plate holder, and the spring catch, G, holds the same firmly in place while plate is in camera.

The plate holder is not shown here, but description of same can be found in SCIENTIFIC AMERICAN, vol. lix, No. 15, which also shows slide and springs inside of camera for holding the plate.

Instead of using leatherette, as suggested, I used two thicknesses of black silesia well pasted together, but find there should be a smooth lining to avoid injuring the film.

In making bellows, H, directions given in SCIENTIFIC AMERICAN, vol. lvii, No. 20, were followed, using the silesia for that also and in the same manner as for the holders.

The plate, I, also shown full size in Fig. 2, is for fastening camera to tripod; two of these are used, so either upright or horizontal pictures may be taken. Fig. 3 shows full size of tripod head, the body of which is made of heavy sheet brass and of the pattern shown in Fig. 4.

The wings, or side pieces, W, 1 inch wide, are bent down at dotted line forming a triangle, and edges soldered together and a cap, J, fitted over the end.

The clip, K, and plates, I, are used instead of the usual screw, as it is more convenient, for this camera has to be removed from tripod when plate is changed.

The bolt, L, holds both the clip and cap in place, but allows the former to turn about in any direction.

A screw could be readily substituted for the clip and used with any camera.

The small carriage bolts, M, hold the legs of tripod, which are of ½ inch oak, ⅞ inch wide at top and four feet long. The diameter of head complete is 1½ inches.

The tripod is opened by a twisting motion and is easily adapted to any position.

As there is no ground glass or finder in this camera, small pins are fixed at certain points, N, N' (Fig. 1), approximately in line with edges of plate and center of lens, and by sighting across them the desired view can be correctly placed on the plate. To a person having facilities for doing such work the cost of the whole outfit, aside from time and labor, would be less than one dollar.

Perhaps a better way of constructing the head would be to have a casting made and drill and tap holes for the screws, but that might be beyond the work of many amateurs.

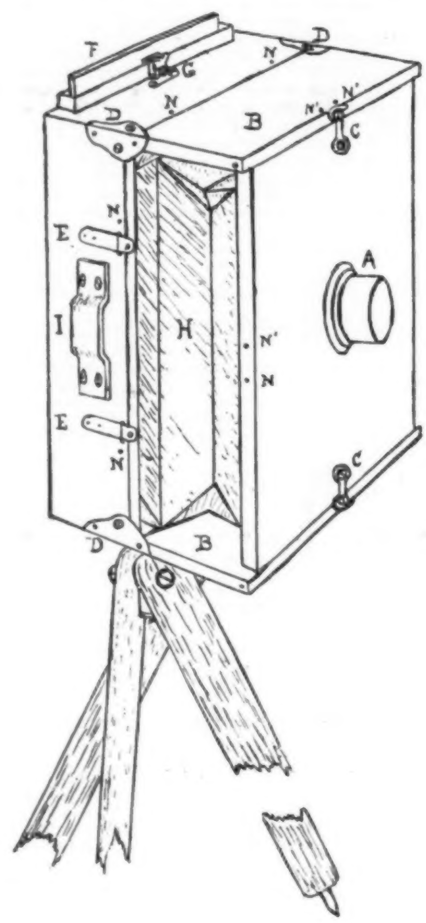


Fig 1

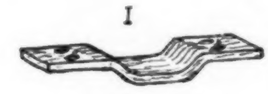


Fig 2

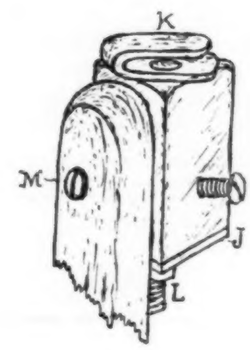


Fig. 3

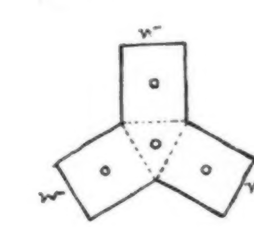


Fig 4.

A FOLDING CAMERA.

[FROM WILSON'S PHOTOGRAPHIC MAGAZINE.]

THE LUMIERE BROTHERS MODIFIED PROCESS OF COLOR PHOTOGRAPHY.

By AUGUSTE and LOUIS LUMIERE.

THE indirect method of photography in natural colors indicated by Messrs. Cros & Ducos du Hauron has not received, up to the present time, a veritable practical application, on account of the difficulties presented by two important points of this method: The selection of the colors, then the obtaining and the superposition of the monochromes. We have devoted ourselves to the study of these two points.

I.

For the selection of the colors we have made use of the screens hitherto recommended: orange, green and violet screens; and we have prepared three series of photographic plates having respectively a maximum of sensitiveness for the rays that the screens allowed to pass.

To reach this result we again took up the study of orthochromatism.

Our experiments, of which the number is considerable, bear upon about one thousand substances.

We first found, as have other experimenters, that all the coloring substances used in concentrated solutions diminish the great sensitiveness of photographic preparations. These substances, attaching themselves to the substratum of the silver salt, color it, and pro-

duce the effect of a screen placed before the sensitive plate. This action, which is a purely physical one, presents no interest, since the same result may be obtained by using suitable screens. We know that outside of this physical action a few coloring substances employed at times in very weak proportions have the property of increasing the sensitiveness of the silver salts for certain colors without diminishing in a notable manner their general sensitiveness.

The local sensitiveness imparted by these coloring substances does not correspond to the radiations absorbed by the coloring matter, but to adjacent radiations, generally less refrangible. For example the solution of erythrosine J shows a band of absorption in the blue-green of the spectrum, while the sensitizing effect which it produces manifests itself in the region of the yellow and the commencement of the green. This sensitizing effect corresponds sensibly to the spectrum of absorption of the argentic combinations of erythrosine J.

The greater number of sensitizers have led us to the same results.

The coincidence of the sensitizing effect and of the spectrum of absorption of the argentic combination of the coloring matter is not absolute, and this is made clear if we remark that the coloring matter also acts physically, as a screen, in coloring the substratum of the silver salt. This physical effect tends to counterbalance the chemical effect, and, according to the concentration of the coloring solution, these two actions have a very variable result.

We reach then this first practical and interesting conclusion:

It is important to select as sensitizers the coloring substances whose effect manifests itself when used in very small quantities.

These bodies alone produce added effects. In making their experiments with orthochromatism the divers operators up to the present time have only used the commercial coloring substances; now these substances represent but a small portion of the organic bodies possessing coloring properties.

The commercial colors are those which combine the qualities required in dyeing; that is to say, solidity when exposed to the light, cheapness, and the property of fixing themselves with or without a mordant on the different woolen, silk, or cotton textiles. These sought for conditions, which are only met with in the substances found in trade, have no value from a photographic point of view, and in a general way the substances that are not used in dyeing, and which possess other properties more suitable for the purpose occupying our attention, are much more interesting.

Taking the above considerations as a basis, we have prepared coloring substances hitherto not used, and have found in a great many of them remarkable sensitizing properties: such are, for example, the tartreines, citreines, oxaleines, succineines, etc.; chlorated, bromated, or iodated products arising from the condensation of acids or of organic anhydrates, with resorcine, metamidophenol, or the homologues of these bodies.

It would require too much space to enter here into the details of the experiments with these substances; they prove that the sensitizers indicated up to this day form but a very small minority of the sensitizers that organic bodies can furnish. The field of orthochromatism has been limited because experiments have been confined to the commercial products made for a purpose which has no connection with orthochromatism.

Having at our command documents relating to the study of more than one thousand coloring substances, we have been able to select mixtures of sensitizers corresponding as exactly as possible to the radiations passing through the violet, green and orange screens, whose use is indispensable for obtaining the three plates representing as negatives the image of the elementary rays, yellow, red and blue; and we have prepared three series of photographic plates presenting a sensitiveness as great as possible to these violet, green and orange rays.

II.

The selection and the superposition of the monochromes have been realized, thanks to the use of a photographic process, with bichromatized mucilages without transfer.

Glue, soluble in cold water, bichromatized, which does not give photographic images with their half-tones when used alone, acquires this property when substances insoluble under certain conditions are added to it.

If we add, for example, to a solution of glue at 10 per cent. 5 per cent. of bichromate of ammonia and from 5 to 10 per cent. of emulsified bromide of silver, and spread this preparation in a thin coating on a glass plate, we obtain a sensitized surface to be exposed to the light under the negative to be reproduced. When the exposure is sufficient the plate is washed in cold water, and we obtain in this manner an image scarcely visible, formed by the insoluble mucilage, an image that may be colored with suitable dyes.

The bromide of silver is afterward got rid of by a suitable solvent, hyposulphite of soda, for example.

This process gives with the greatest facility prints of all colors, with all the gradations of the tints of the negative. The bromide of silver may be replaced by other insoluble precipitates. With this process it is easy to obtain polychrome tints by using the principle of the method of Messrs. Cros & Ducos du Hauron.

For this proceed to obtain successively on one plate three monochrome images, red, yellow and blue, coming from three corresponding negatives, care being taken to isolate each image from the preceding one, by an impervious coating of collodion, for example.

This easy method enables us, by the use of dyes more or less concentrated, or by a simple removal of the color by means of water, to vary the intensity of the monochromes, to modify, if necessary, the effect of the first three coatings by the addition of a fourth, of a fifth, and even more; moreover, it renders the adjustment very easy and makes possible to transfer to paper the ensemble of these impressions.

One of the first specimens of photographs in colors thus obtained, the specimen which accompanies this communication, shows all the practical advantages which it is now possible to obtain from a method for so long a time neglected.

Lyons, May 8, 1895.

AMUSING PHOTOGRAPHY.

HOWEVER far a photographer may carry the love of his art, there is no doubt that he would hesitate to fall from the top of a ladder in order to prove the rapidity of his apparatus by pointing his objective at himself. And yet the photograph that we submit to our readers seems to be the realization of such an experiment.

Despite all, the skillful operator that it represents, carrying pictures, ladder, etc., along with him in his fall, has not experienced the least uneasiness, not even as much as will certainly be felt by our readers at the sight of the tumble represented.

The mode of operating in this case is very simple. The photographic apparatus being suspended at a few yards from the floor of the room, in such a way as to render the ground glass horizontal (say between the two sides of a double ladder—a combination that permits of easily focusing and putting the plates in place), there is spread upon the floor a sheet of wall paper, about six feet in length by five in width, at the bottom

FIG. 1.—THE TERRIBLE FALL.

of which a wainscot has been figured. A ladder, a few pictures, a statuette and a bottle are so arranged as to give an observer the illusion of the wall of a room, that of a dining room for instance. A hammer, some nails, etc., are placed at the proper points. Finally, a 5 by 2½ foot board to which a piece of carpet, a cardboard plate, etc., have been tacked is placed under the foot of a chair, which then seems to rest upon this false floor at right angles with that of the room.

Everything being ready, the operator lies down quietly in the midst of these objects, assumes a frightened expression and waits until the shutter announces to him that he can leave his not very painful position. This evidently is merely an example that our readers will be able to modify and vary at their will.—La Nature.

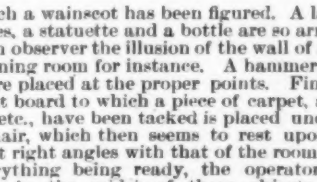


FIG. 2.—Camera Mounted at the Top of a Step Ladder, E E, in Order to Permit of Operating Downward. O, objective; P, board support containing an aperture for the passage of the objective.

PHOTOGRAPHY IN NATURAL COLORS.

A LARGE share of interest was displayed at the recent soirée of the Royal Society in the exhibition by Dr. Joly, of Dublin, of some photographic transparencies upon glass plates, representing various objects in their natural colors.

That every range of color and texture could be dealt with according to the new method by which these were obtained was evident upon examination of the subjects portrayed. The portrait of a gentleman seated on a garden seat showed the flesh tints of the hands and face reproduced with great naturalness.

The straw hat upon his knee, the buff lining partly revealed within, as well as the faint green reflex on the rim where this caught the greenish light reflected from the foliage among which he sat, appeared reproduced with the same fidelity and realism which characterizes the image in the camera.

Pansies of brilliant yellow and brown, deep purple-black, pale blue, snow white and velvety brown grouped in a painted china vase, appeared with equal fidelity in another picture. Other pictures showed an exterior of a red brick building in Trinity College, Dublin, fronted by a lawn with hawthorns, and above the greenish slates a pale blue sky; a reproduction of a water color drawing of an Irish peasant girl wearing a red handkerchief over a blue dress, the warm, somewhat sunburnt flesh tints matching the original drawing with almost faultless fidelity—the original being placed above for comparison; delicately colored Indian china and blue china; a lacquered brass microscope with highly reflecting German silver and copper lacquered finishing; a thin uranium green glass tumbler with a subtile play of green and yellow light, and finally, the visible spectrum.

Such a variety of subjects seems to exhaust, almost, the problems which we can submit to the photographer as tests of the range and power of a method which claims to accomplish color photography.

The general interest to know how such results can be obtained is not very readily satisfied, for, while the procedure actually involved in securing these photographs in colors is of extreme simplicity—in fact, hardly differing from that with which every photographer is already acquainted—the principles which underlie it need some patient thought to master fully.

Those who have followed the recent development of composite color photography will readily grasp the principles involved. In the practice of composite color photography the theoretical principles are applied through a procedure far too cumbrous to be available. In fact, the problem of obtaining the naturally colored image by these methods was solved only by the intervention of an apparatus which will unite by optical projection three separate images. In the new method no such projection is needed.

We can hold the plate in the hand, and looking at it against the light, see the objects in their original colors, and this by taking a single photographic image in the camera in, it may be said, the usual manner.

The operations involved in the new method are as follows: A transparent glass plate, which on first inspection appears to bear a uniform tint and to possess a somewhat silky texture, is placed in front of the sensitive film and in contact with it, when the latter is exposed in the camera. Examination of this plate with a strong lens or microscope shows that it is not homogeneous, but is closely lined over with fine transparent lines of three different colors succeeding each other regularly over and over again and in close juxtaposition.

The plates shown at the Royal Society were divided to a fineness of 200 lines to the inch. This is not sufficiently fine to obviate in some cases a linear texture visible on near inspection of the picture ultimately obtained. A fineness of 300 lines to the inch practically accomplishes this, as was demonstrated on a photograph of a group of wall flowers.

The plate which has been exposed under this screen is developed in the usual manner. The result obtained we may regard as embodying in the single minutely divided linear image all three separate pictures required in the practice of the methods of composite photography already alluded to, each produced by a special color selective action. Although possessing this triple character, the negative differs little in appearance from the ordinary negative, or a positive subsequently obtained, from the ordinary positive or transparency.

The exposure in the camera is of course somewhat longer, for it is evident that whatever principles are employed, only visible light can be utilized in obtaining a photograph in natural colors, and of this a part is stopped by the ruled screen. Hence a well-lit landscape may take from three to five seconds with fairly open stop and rapid lens.

Of course, neither the negative nor positive so far obtained shows any color. But if now a plate ruled in three tints, which again are chosen according to color vision theory, is correctly applied to the positive, and if we hold the combined glasses to the light, there is obtained the appearance of the original image as a brilliant transparency in natural colors.

The choice of the tints upon the two screens is based upon the now old hypothesis that all our color sensations, of however varied and subtile tints, are referable to the action, single or combined, of but three sensations (fundamental sensations as they are designated), transmitted to the brain by the color sensitive nerves of the retina. Such a hypothesis, if true, implies evidently that any one sensation must be excited by a considerable range of wave lengths, for otherwise that band of light, the spectrum, wherein the several wave lengths composing white light are, as it were, sorted out and arranged according to wave length, would appeal to the eye only in the red, green and violet; intermediate wave lengths, if not competent to excite the primary sensations in the nerves, remaining, of course, invisible.

The sensation which we term yellow, excited at a particular part of the spectrum situated between the red and the green, is, in short, explained as a resultant sensation arising from a simultaneous excitation of both the red and green transmitting nerves of the retina. Carrying this idea still further, physicists have by measurements, carried out upon normal as well as color blind vision, succeeded in determining the relative degrees of stimulation experienced by each of the three several color sensitive nerves, supposing these separately exposed to stimulation by the various wave lengths of the spectrum, or, in other words, by the different visible wave lengths of nature.

In Dr. Joly's pictures the curves embodying Koenig's measurements are taken as the basis of the color principles employed. It is sufficient to add that the particular tints chosen for the three lines upon the taking screen are such as will transmit those wave lengths which excite severally the three fundamental sensations and transmit them in the same degree as they excite those sensations. In fact, the portion of the sensitive plate underlying a "red" taking line is excited or acted on by the light rays in a degree proportionately to the degree in which the nerve itself would have been excited to transmit a sensation of redness if exposed to this minute portion of the image. And similarly the green and violet taking lines are more or less transparent to light rays as these are more or less competent to excite green or red sensation. Tints that will act in this way bear to the eye, exercising its triple apparatus of color vision, an orange yellow, a greenish yellow and a blue-violet color. These, then, are the tints

repeated over and over again upon the taking screen. Opacity upon the negative being interpreted as transparency upon the positive, it results that a deep red object, for example, will be crossed by transparent lines upon those parts of the positive image which interpret the action of the "red" taking line in the negative image. The green and violet lines, on the other hand, will be all represented in the image as opaque areas, for their action, when the negative is being taken, will be to stop all dark red light reaching the plate, such rays not exciting green or violet sensation.

The operation of placing the ruled cover glass upon the positive is only correctly accomplished when each of the three fundamental colors upon it lies against a linear area which records the selective action of the taking screen for that particular color sensation.

In the case supposed, a red line will cover a clear space, whereas the blue and violet lines will be blocked out. Hence, the final result will be the red coloration of the image. In general, two lines will act, as the green and red to produce yellow, or the violet and green to produce blue. Or, again, a pure white object upon the final picture will, when examined by a lens, show the three lines, red, green and blue, acting with equal brightness. Thus, although neither white, yellow, blue, pink, nor brown, etc., exists upon the covering screen, all these finally appear correctly as they existed in the color of the original object.

The procedure, in fact, is one in which the three "fundamental" colors are impartially supplied by the covering screen; but the previous experience of the sensitive plate during exposure is such as insures the positive plate selecting among these colors according to the original colors of the image.

It is in this manner that the inability of physicists to find a sensitive substance, which itself will faithfully adopt and keep the colors of the image, is surmounted.

Were such a substance indeed forthcoming, it could not more faithfully reproduce the true colors of nature.

And this leads us to remark that the particular nature of this procedure, resulting in a complete independence of the almost inevitable ultimate fading of pigments, is of no small moment, more especially in the scientific registration of color. For it is seen that the color register is really carried in the silver deposit on the negative or positive, which may, with ordinary care in the photographic manipulation, be rendered quite permanent. And a fading of the tints on the covering screen may at any time be made good by applying a fresh screen. Copies, too, of a picture may be multiplied to any extent.

So far as this new departure concerns the amateur, it is to be presumed that the labor of preparing the screens will not fall to him. His part in obtaining a photograph in natural color will consist in exposing an isochromatic dry plate beneath the ruled screen; and subsequently, temporarily or permanently, applying the ruled cover glass. This is an easy operation. Indeed, a very little practice enables one to do this so readily that it is quite possible to run through a series of lantern plates at an exhibition with the aid of but one covering screen, adjusting and temporarily clamping it over each plate before it is put into the lantern.

However, there is every reason to believe that the commercial production of the screens will not be attended with any difficulties necessitating a high price. The lines are ruled with colored inks, made up of gum and gelatine mixed in certain proportions, on a gelatine coated plate, and we believe that all difficulties as to the durability of the pens employed and the nature of the inks have been surmounted.

That this new development will greatly increase the votaries of photography is hardly to be doubted, seeing that by this method a naturally colored image is as readily produced as one in black and white.—London Times.

[FROM CASSIER'S MAGAZINE.]

THE MAXIMUM POSSIBLE EFFICIENCY OF GALVANIC BATTERIES.

By HENRY MORTON, Ph.D.

SOME recent publications and other intimations indicate that, with the general revival of business, there are likely to be brought before the public various schemes, such as some of those discussed in the writer's recent articles on "Engineering Fallacies," in this magazine, in which electric energy, derived from galvanic batteries, will be relied upon as the source of power. In view of this, it would seem as if a few words on the above subject might be timely, and the writer has therefore ventured to put into shape the appended calculations.

To discuss this question in an exact and numerical manner, it will be necessary to indicate with precision what class of batteries are referred to, and the writer would, therefore, say at the outset that he refers only to those which long experience has proved to be the most efficient in supplying large currents, excluding those of the Leclanché type which yield only feeble currents.

In all the batteries here referred to, there are the following common features:

First. The energy is derived from the combination of zinc with dilute sulphuric acid. Second. The supply of oxygen required for this combination is obtained by the decomposition of water or some other compound in aqueous solution. In other words, the batteries here considered are the Smee, the Daniell, the Grove and the various forms in which chromic acid is the oxygen-supplying substance.

This being premised, we can begin with the following general statement of principles:

First.—The source of energy being the reaction between the metallic zinc and the dilute acid, its amount can be expressed in British thermal units as follows:

Oxidation of zinc, 2,340 B. T. U.; solution of oxide in dilute sulphuric acid, 666 B. T. U.; or, in all, 3,006 B. T. U. as the total energy developed by the union of the zinc and acid. No arrangement of parts or employment of one material or another in other parts of the cell or for other parts of the reaction can add anything to this, but on the other hand, there must always be more or less subtracted from it to meet the demands of the reaction, to say nothing of internal resistance of the solutions, local action, etc.

Second.—In order that the zinc should combine with the acid, the hydrogen, whose place it takes, must be driven out or otherwise taken care of, and this will demand an expenditure of energy, greater or less, but always considerable.

For example, in the Smee battery the hydrogen is simply driven out in bubbles of gas. To do this requires 2,106 B. T. U. for each pound of zinc dissolved. Taking this from 3,006, leaves only 900 B. T. U. as even possibly available from each pound of zinc consumed in a Smee battery, not counting losses coming from local action, resistance, etc.

This difficulty was realized at an early period and was met by supplying oxygen to take up the hydrogen, and so avoid the great loss involved in expelling it.

To supply this oxygen, various substances have been used, but the only ones of practical importance are sulphate of copper, nitric acid and chromic acid. But even with these, more or less energy must be expended in decomposing them and securing their oxygen. The energies involved are:

	B. T. U.
Sulphate of copper, Daniell battery. ..	1,587
Nitric acid, Grove or Bunsen battery...	283·6
Chromic acid, Poggendorff battery. ...	178·5

If these various amounts are subtracted from the maximum thermal value of the zinc in sulphuric acid combination, we will have for the several batteries:

	B. T. U.
Smee battery, as before.................	900
Daniell battery.	1,419
Grove or Bunsen battery..............	2,722·4
Poggendorff (chromic acid)	2,827·5

These figures represent the absolute maxima of energy which a pound of zinc could develop in these forms of battery, excluding all losses from resistance, etc. To get a practical view of these results, however, it will be necessary to reduce them to equivalent foot pounds of work and to horse power rates of doing work.

Joule has shown that each British thermal unit is equal to 772 foot pounds, and this means that the energy expressed by the heat which will raise 1 lb. of water 1° Fahrenheit (this is the British thermal unit) would lift 1 lb. 772 feet, or 772 lb. 1 foot. If, then, we multiply the figures given above, we shall have the various energies expressed in foot pounds of work. In other words, a pound of zinc, consumed in these various batteries, would develop the following numbers of foot pounds, all losses from resistance, etc., being excluded:

	Foot pounds.
Smee battery....	694,800
Daniell battery,......................	1,095,468
Grove battery.........................	2,101,694
Poggendorff battery...................	2,182,820

If, in each of these batteries, 1 lb. of zinc were consumed in a minute, then the above numbers of foot pounds would represent the work developed in a minute in each case, and to turn this into horse power we should divide each number by 33,000, because a horse power is a rate of doing work of 33,000 foot pounds each minute. This will give us the horse power represented by the solution of 1 lb. of zinc each minute in each battery.

Smee battery......	21·05	H. P.	for one	minute.
Daniell battery....	33·19	"	"	"
Grove battery ...	63·66	"	"	"
Poggendorff b'tt'ry	68·57	"	"	"

Such a rate of consuming zinc as a pound a minute would, of course, require an immense galvanic battery and indeed it is usual to express the consumption of fuels generally in pounds per hour. To get the horse power due to the consumption of zinc at the rate of a pound an hour, we divide the above figures by 60, and this gives the horse power developed by a pound of zinc consumed during an hour as follows:

Smee battery..........	0·35,	or about	$\frac{1}{3}$	H. P.
Daniell battery........	0·55	"	$\frac{1}{2}$	"
Grove battery	1·06	"	1	"
Poggendorff battery ..	1·14	"	$1\frac{1}{4}$	"

This shows that in the best forms of battery an allowance of one horse power for each pound of zinc consumed per hour would be a liberal one, if something is allowed, as it must be, for the resistance, local action, etc.

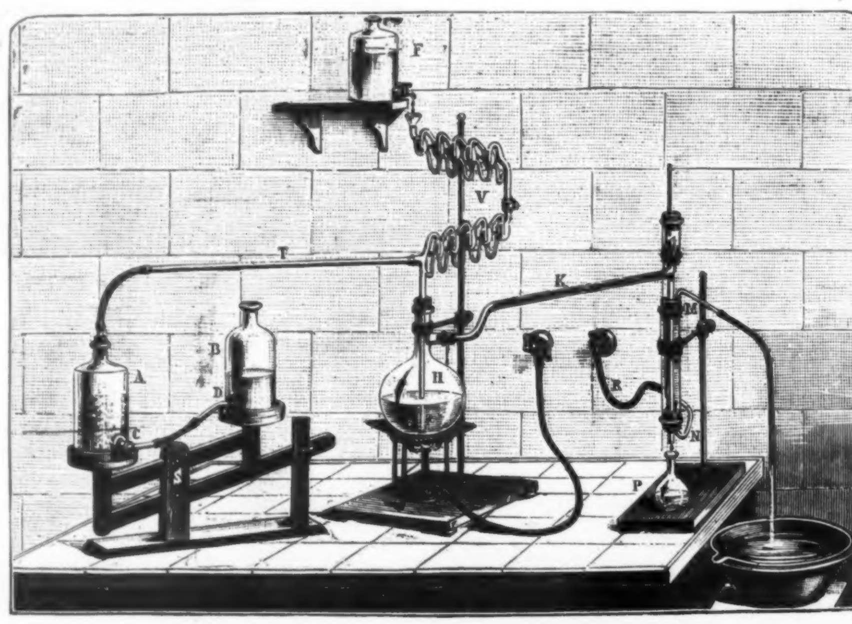
It may, however, be asked: If such an improvement has been made as above shown from the Smee battery giving one-third to the Poggendorff yielding $1\frac{1}{4}$ horse power, may we not expect further improvements as great in amount? To this I answer certainly not in this class of batteries. The entire energy of the reaction between the zinc and dilute acid is 3,006 British thermal units. This would represent 2,320,632 foot pounds, or 70·62 horse power for one minute, or 1·17, say $1\frac{1}{4}$, horse power for one hour, and this would be an absolute maximum which could never be reached, far less exceeded.

Of course, if we could use some other, and more efficient, reaction than that between zinc and sulphuric acid, some gain might be secured, but nothing of that sort has ever been accomplished, nor from what is known of the combining or thermal equivalents of the available elements, is much to be expected in that line. At all events, we may well accept this as a certain fact, that in any known form of galvanic battery the round figure of a pound of zinc per horse power per hour is an outside figure for efficiency, and when any one asserts that more than this has been secured, there is certainly some mistake or fraud.

ARTIFICIAL ALCOHOL.

THE alcohol that we produce and consume is obtained, as it was in remote times, through the distillation of alcoholic liquids. We have improved only the distillatory apparatus and the method of preparing the saccharine material and regulated the fermentation. At bottom, the principle is the same. We always ask Dame Nature to convert the elements into hydrates of carbon, starch and sugar for us by her powerful methods. Our science permits us to finish the rest and appropriate the natural products to our multiple needs.

Industry, aided by the physical sciences, is asking to be freed from the yoke that it has been wearing for centuries; and it is right. The methods employed by nature are too slow, and often uncertain in consequence of climatic conditions, fine or bad weather, etc. The manufacturer desires to prepare in a few days or a few hours what time takes months and years to produce. He wishes to have it in his power to prepare at will and at any moment determinate quantities of the substances contained in plants or in the products of animal life.



APPARATUS FOR THE PRODUCTION OF ARTIFICIAL ALCOHOL.

The conquests of science are already very great in this direction. Colors, perfumes, medicines, sugar, etc., may be prepared artificially by the hand of man alone without the least intervention of the natural forces.

We are now going to show how one has succeeded in preparing artificially, and from minerals, alcohol freed from the injurious principles that ordinarily accompany it and against which hygienists and physicians fulminate.

Chemically considered, alcohol is a compound of carbon, hydrogen and oxygen. These elements are abundantly distributed upon the earth. Wood or coal may give us carbon in the form of charcoal or coke. Water contains hydrogen and oxygen.

Mr. Berthelot was the first to obtain synthetic alcohol, that is to say, alcohol prepared artificially and starting from carbon and hydrogen. Upon causing an electric arc to form between two carbon rods placed in a globe traversed by a current of hydrogen, we obtain acetylene. Upon combining this gas with nascent hydrogen, we obtain ethylene, which, absorbed by concentrated sulphuric acid, is converted into sulphovinic acid, which, diluted with water and raised to ebullition, gives alcohol. This process is too expensive to enter into practice to dethrone grape or potato spirits; but, since electro-chemical science has permitted of obtaining acetylene gas very cheaply, the production of artificial alcohol has been studied anew and simplified. We may recall the fact that this product is obtained by decomposing carburet of calcium with water, the carburet itself being produced by very strongly heating a mixture of lime and coke in an electric furnace. With hydraulic force a ton of carburet of calcium costs about twenty dollars, and a ton of carburet decomposed by water disengages 880 pounds of acetylene. The following are the reactions that permit of very easily producing alcohol with acetylene,

The sulphate of protoxide of ammoniacal chrome absorbs this gas and converts it, especially when hot, into ethylene. The reagent gradually passes to the state of chloride of peroxide. In order to bring it to the state of protoxide and make it capable of absorbing acetylene anew, it is necessary to reduce it by zinc or iron and sulphuric acid. But such reduction is much more economical if nascent hydrogen disengaged by the electrolysis of water be used as the reducing agent. The transforming reagent may remain constantly with the same activity and continuously change an indefinite quantity of acetylene into ethylene. It suffices that the power of the current be sufficient to produce the hydrogen necessary, say a tenth in weight of the quantity of acetylene brought into play. The ethylene, once produced, is absorbed by hot sulphuric acid (80-85° C.) This acid is diluted with water and raised to ebullition. Alcohol is then disengaged. Upon a distilling column being used, alcohol of from 90° to 96° is obtained.

The accompanying figure represents an arrangement that permits of preparing artificial alcohol in a continuous manner, and in hydrogenating the acetylene at the moment of its formation in the very apparatus that produces it. Into the flask, A, is put a mixture of carburet of calcium and zinc (4·4 pounds of the first and 5·5 of the second). Into the flask, B, is put water acidulated with sulphuric acid (5 quarts of water and 6 pounds of acid). The two flasks are connected by a rubber tube, CD, and placed upon a support, S, that permits of raising or lowering the flask, B, according as one wishes to increase or decrease the current. The acidulated water attacks the carburet and the zinc, and hydrogen and acetylene form; but the two gases immediately combine to form ethylene, which is disengaged through the tube, T. There it passes into the balls of an Otto apparatus, V, in which it dissolves in contact with the hot sulphuric acid that gradually and constantly flows in from the flask, F. The acid, saturated with gas, flows into the balloon, H, to the bottom of the water that it contains and which is raised to ebullition. In this balloon the product is decomposed into acid and alcohol. This latter volatilizes with water and becomes enriched in the tube, K, containing strips of copper and serving as a distillation column. The pure alcohol condenses in the refrigeratory, R, which is cooled by a current of water. The pure alcohol is collected in the receiver, P.

The alcohol obtained by this means is absolutely pure and free from the products that usually contaminate the alcohol of grain, beets, etc., and render it so dangerous to the health of those who absorb it. This artificial alcohol is, therefore, a hygienic one, an alcohol prepared without rectification, always the same and always free from injurious principles. This result will be appreciated, especially since the government is occupying itself with regulating the tax on beverages.

Will artificial alcohol, from an economical standpoint, be able to compete with the industrial alcohol such as now manufactured from potatoes, beets and grain? Such is the question that presents itself in the first rank, our alcohol having its diploma for hygiene.

The process that we have described permits of obtaining alcohol at about seven cents a quart. This is a splendid enough result, but upon using hydraulic power to produce the carburet of calcium for obtaining the hydrogen, instead of using zinc and acid, this cost would be reduced to six cents. From a practical point of view, the absorbing reagent has been improved and the acid replaced by a salt that is constantly regenerated without the necessity of concentration. The most costly part of the operation has thus been suppressed.

The alcohol under such circumstances costs no more than from three to five cents, at 96° and in the greatest state of purity. As may be seen, the electric industries have in reserve for us quite an encouraging future. Nothing would be more curious than to see the manufacture of alcohol and brandies transported to the mountains, and the enormous power that is now lost, and awaits the desired moment to produce effective work, thus utilized.—La Nature.

[FROM THE NINETEENTH CENTURY.]

RECENT SCIENCE.

I. ARGON.

No substance in nature seemed to be better known to chemists than atmospheric air. The composition of air taken from the most different localities and altitudes had so often been analyzed by the best chemists and physicists that up to the last few years it seemed almost inadmissible that any gas existing in the atmosphere should have escaped detection. However, modern chemistry disposes of such perfect methods of analysis and our modern laboratories are supplied with such wonderfully precise instruments—it is sufficient to say that in a modern weighing the incertitude is inferior to $\frac{1}{50000}$ part of one ounce—that when the study of air and other gases was again taken in hand with the aid of the new instruments and methods, a vague suspicion began to grow up. "After all," it was said in scientific circles, "atmospheric air is not so very well known," and it possibly may contain small quantities of some unknown gases mixed with its principal components—nitrogen and oxygen, carbonic acid and vapor of water.* These suspicions are now fully confirmed. When the researches of Lord Rayleigh and Prof. Ramsay were published in full, it became evident that atmospheric air contains over one-half per cent. of some gas (or maybe gases) formerly unknown, and that this gas—named argon by its discoverers—is possessed of chemical properties which offer many a puzzle to the chemist. The distrust which the announcement of the discovery was met with in August last has been dissipated since, and the question, What is argon? stands now foremost.

Is it an element which, like hydrogen or oxygen, cannot be decomposed into still simpler bodies—a "chemical individuality," as Mendeleeff says, which maintains its individual character even when it combines with other individualities? Or is argon a mixture of several new elements? Or is it a compound of well known elements which were never met before in that special combination? These questions press themselves upon every one's mind. However, up to the present date they have not been answered, and most probably the answer will not be given for some time to come, not only because the discovery of argon was immediately followed by the discovery of several other gases, but also because argon is so peculiar in its behavior as to raise a host of questions of paramount importance for chemistry. The general reader, accustomed to get from science ready results, may, therefore, feel disappointed when, after having perused the following pages, he only finds a number of new unsolved problems cast upon science. But, to follow step by step the inquiry which is now going on, to share the hopes and doubts of the explorers, and thus to be initiated into the mysteries of scientific research itself, and into the methods of discovery of scientific laws, is perhaps even more interesting and certainly much more suggestive than to learn some time later the bare results.

For the last seven years Lord Rayleigh has been engaged in remeasuring the densities of the commonest gases, with all the precision obtainable from modern appliances, and his work was soon recognized to be a standard work. However, even in the earlier stages of his researches, while he dealt with oxygen and air, there appeared certain discrepancies between his otherwise most accurate results, which, precisely because the measurements were so perfect, could not well be explained by unavoidable errors and created a certain uneasiness as to the permanence of the constitution of air. But when he came later on to deal with nitrogen things took a more serious aspect. Nitrogen is an element; and, whether it be obtained from the air or from one of the nitrogen compounds, such as ammonia, it must always be the same gas, endowed with the same physical and chemical properties. And yet this was not the case. Nitrogen obtained from the atmosphere by any one of the usual methods was regularly by about one-half per cent. heavier than nitrogen obtained in the chemical way from some compound. In each of the two sets of determinations the measurements beautifully agreed together; but the two sets totally disagreed, although all possible precautions had evidently been taken to prevent contamination by other gases, and a strong control was exercised to detect contamination if it had taken place. The discord had to be explained.*

The nearest explanation was, of course, to find fault with the chemically prepared nitrogen; notwithstanding all precautions, it might still contain some lighter gas—hydrogen, for instance; but test experiments were installed and compelled the rejection of this explanation, so that there remained but one other alternative, namely, that the atmospheric nitrogen, supposed to be the purest of the two, was not pure at all; that it contained some heavier gas which enters into the composition of the atmosphere to no small amount, but in some way or another had hitherto escaped notice. Lord Rayleigh naturally hesitated to draw a conclusion so much opposed to all current opinion, and in his perplexity he applied through the medium of Nature to chemists, asking them to aid him with their suggestions.† The suggestions came, and in a great number; but none of them explained the difficulty. Some time later Prof. Ramsay asked and obtained permission to investigate the matter, and the two explorers, the physicist and the chemist, working first separately, made the necessary arrangements for isolating the new heavier gas by two different methods. They obtained it nearly pure, and on account of its unwillingness to enter into any chemical combination they proposed for it the name of argon. The discovery was announced at Oxford at the last meeting of the British Association.

This announcement, as already mentioned, was met with a great deal of distrust, which only grew stronger as time went on, and nothing was heard during the next five months in support of so important a statement. It was only after all the details of the researches were made public at the end of January last‡ that all doubts as to the real existence of a new constituent of the atmosphere were removed and the whole inquiry was recognized by competent judges as an exemplary chemical research.§

The first step to be made in an inquiry of this sort is evidently to obtain the new body in sufficiently large quantities for chemical analyses. This proved, however, to be a hard task. If argon easily combined with other bodies any amount of it could be obtained, because the nitrogen of air, of which there is an unlimited supply, contains as much as one per cent. of argon. But the new gas refuses to enter into chemical combinations, and it is necessary to absorb all the oxygen, nitrogen, carbonic acid, and so on, from a given considerable volume of air, and to obtain argon as a residue. Yet nitrogen in its turn is also a very inert body, which it is easy by no means to force into a chemical combination; so that, after oxygen and the rest have been eliminated, there is still the difficulty of removing nitrogen from the mixture. It must, for instance, be passed for hours again and again over some red hot magnesium or lithium,‖ until most of it having combined with the metal, a small quantity of argon is obtained, which yet is never quite free from nitrogen. Or else atmospheric air mixed with some oxygen is sent through a tube in which electric sparks are passed, and while the nitrogen of the air is thus induced to combine with oxygen, argon remains; but this operation, too, must be continued for hours, and the produce is never pure. There is, finally, a third method, namely, to send air through a porous membrane which separates gases of different densities, but nothing is gained by it in rapidity. All this is, of course, most wearisome, and even has been made a reproach to Lord Rayleigh and Prof. Ramsay; but chemical bodies must be taken as they are, and those of them which, like argon, refuse to yield to chemical routine are perhaps the most conducive to an extension of chemical knowledge.

Whenever a new body is discovered, its leading physical properties are always the easiest, and therefore the first, to be determined. We thus know about argon that it is a colorless and inodorous gas, having about twenty times (19·7 to 19·9) the density of hydrogen, and much more soluble in water than either oxygen or nitrogen. Accordingly, the air which is dissolved in water contains a larger proportion of argon than free atmospheric air; in unboiled water we drink a greater proportion of dissolved argon than we inhale of it while breathing, and this property may prove of great importance for vegetation if argon enters, as it probably does, into the composition of plants. It requires also a very low temperature for liquefaction: Olszewski, the Cracow professor, whose admirable achievements in the liquefaction of gases have lately been rendered popular in this country by Prof. Dewar, has turned some argon which was sent to him by Prof. Ramsay into a liquid at a temperature of 305° F. below zero, and into a block of opaque ice at 310° below zero.*

But these physical properties tell us nothing about what argon is, and all attempts to unveil its chemical nature have hitherto failed. Even Moissan, with his powerful electric furnace, could not overpower its inertness. Neither fluorine, which is one of the most active elements, nor titanium, boron, and lithium, which readily combine with nitrogen, could be induced to combine with argon. Berthelot alone, using the silent electrical discharge, has achieved a partial success; he made argon combine with benzine and obtained a yellow resinous substance; but the quantity of argon he had received from Prof. Ramsay was so small (a little over two cubic inches) that nothing could be said about the produce of combination beyond its being similar in aspect to the products of combination of nitrogen with benzine.† Negative properties are thus all we know about the chemical nature of argon. Even the spectroscope—this precious reconnoitering instrument—is undecided in its indications. The spectrum of argon is quite characteristic. No other known gas or vapor, Mr. Crookes writes, gives a similar spectrum. But when a glass tube filled with argon is made to glow under the electrical discharge, and the glow is examined with the spectroscope, two different spectra appear—one of them chiefly in the red and the other chiefly in the blue—according to the energy of the discharge. These two spectra may of course indicate that argon is a mixture of two gases, although it is known that nitrogen and other gases also show two spectra under similar conditions; but Olszewski has found that argon has such a definite temperature of liquefaction, as well as such a definite critical temperature and pressure,‡ that, if it be a mixture, the mixture must contain but a small proportion of another gas. It must also be borne in mind that, under our present knowledge of the spectral analysis, it remains but an auxiliary to the chemist; it offers one of the means of preliminary exploration, but any positive decision rests with the regular chemical analysis.

What, then, is argon, or, at least, the gas which prevails in what science already names argon? From all that has been said it does not appear probable that it is a chemical compound. A compound could hardly have resisted so many chemical and electrical tests. It has, on the contrary, all the behavior of an element; and in such case what is, then, the weight of its atom? In other words, taking the weight of an hydrogen atom for a unit, what is the corresponding weight for argon? Its density being twenty times the density of hydrogen, we know that its molecule must weigh forty times as much as an atom of hydrogen; but for argon, as for each new body whose compounds are not yet known, the difficulty is to decide how many atoms its molecule contains. If it were built on the same pattern as the molecules of hydrogen, or oxygen and many other gases, each of which consists of two atoms locked together, there would be no difficulty. We should say that its atomic weight is 20 (twenty times the weight of an hydrogen atom) and argon would find a vacant place in the row of elements between fluorine (atomic weight, 19) and sodium (23), although it must be said that its inertness would badly clash in this case with the chemical properties of its next door neighbors.

In the Mendeleeff periodic classification of elements it would also find a ready place, and even would give an additional symmetry to the system.§ Moreover, Dr. Gladstone in this country and Mr. Hill in America have simultaneously indicated in connection with argon a striking analogy in the growth of the masses of many elements which increase alternately by one unit and by three units; and a body having an atomic weight of 20 would further confirm this symmetry;‖ while Lecoq de Boisbaudran, who also has elaborated a system of classification of elements, requires in his turn a body having an atomic weight of a little over 20, and very inert, to fill up a gap in his system.¶ All these analogies are, of course, very interesting, but in the meantime we have no reason to maintain that argon really is the required element; the more so as another hypothesis seems to be much more or, at least, equally probable.

All hitherto obtained argon was contaminated by

* Mendeleef, in his Principles of Chemistry (English edition, vol. i, p. 228, note 12), already expressed the opinion that under the electrical discharge the nitrogen of the air may be partially dissociated, giving origin to monatomic molecules (N). Helmholtz, having received the news of the discovery of a new constituent of the atmosphere, said that he always thought "that there was something more in the atmosphere" (Lord Rayleigh's lecture on Argon at the Royal Institution).

* The average weight of one liter of nitrogen was 1·2572 grammes when it was derived from the atmosphere, and 1·2506 grammes for chemically obtained nitrogen.

† September 29, 1892, vol. xlvi, p. 512. See also his two subsequent communications to the Royal Society.

‡ Proceedings of the Royal Society, January 31, 1895; Nature, February 7, 1895, vol. li, pp. 347-356.

§ Mendeleeff, Proceedings of the Russian Chemical and Physical Society, March 2 (14), 1895; and in Nature, vol. li, p. 543; Berthelot in Comptes Rendus, February 4, 1895, tome cxx, p. 235 sq.

‖ This last, the lithium method, has been experimented upon with success at Nancy, by Guntz (Comptes Rendus, April 8, 1895, vol. cxx, p. 777).

* The corresponding temperatures for nitrogen are −318° and −353° F. As to oxygen, it has not yet been brought into a solid state, but it liquefies at −297°. The critical temperature for argon is −186° F., and the critical pressure amounts to 50·6 atmospheres.

† From a subsequent communication of Berthelot we learn that another sample of argon, also prepared by Mr. Ramsay, behaved quite differently from the former. Eighty per cent. of the former combined with benzine, but only six to ten per cent. of the second would enter into the same combination (Comptes Rendus, April 16, 1895, tome cxx, p. 798). Did the former contain so much nitrogen?

‡ For critical temperatures and pressures see a previous "Recent Science" review (Nineteenth Century, April, 1894).

§ By giving an eighth group (or column) to the second series, which is an "even" series—several other even series also having their eighth groups—and by having certain properties characteristic of the eighth groups or columns.

‖ J. H. Gladstone's letter in Nature, February 21, 1895; and E. A. Hill's "Argon, Prout's Hypothesis, and the Periodic Law," in American Journal of Science, May, 1895, p. 405.

¶ Comptes Rendus, 1895, tome cxx, p. 361.

nitrogen, which is lighter than argon; consequently, we cannot be sure that its density is exactly 19·9; it may exceed 20, and even approach to 21, in which case its molecular weight would be about 42; and then argon, in all probability, would be nothing but an allotropic form of nitrogen. We know, indeed, that the atmosphere contains a varying proportion of ozone, which is nothing but a condensed form of oxygen grouped in molecules of three atoms each (O_3), while the molecule of common oxygen contains only two atoms (O_2). It is therefore possible that nitrogen, too, might appear in two forms: with a triatomic molecule (N_3) in argon, and with the usual biatomic molecule (N_2) in ordinary nitrogen. This is the hypothesis toward which Mendeleef, Berthelot, and Professor Dewar incline, and various circumstances yield it a certain support, namely, the concurrent appearance of argon and nitrogen in nature, the difficulty of separating them from each other, their inertness, exaggerated in argon, their common lines in the spectra, their double spectra themselves, and the outer resemblance between their benzine compounds in Berthelot's experiments; perhaps also the fact that a small quantity of argon was found in nitrogen obtained from one of its compounds.*

However, certain measurement relative to the heat-absorbing capacity of argon—too technical to be discussed in this place—seem to point out that, under our present conceptions as to the arrangement of atoms in molecules, we ought to consider the molecule of argon (like the molecule of mercury vapors) as consisting of one atom only. In this case the weights of both its molecule and its atom would be equal to 40. But not only is there no room for such a body in the periodical system—the place being already occupied—but argon would stand by its chemical inertness as a unique exception in a classification which indicates the chemical properties of every other element from its position in the system. The periodic law will certainly not be thrown overboard to suit this unique exception; so that chemists and physicists may perhaps have to revise their present ideas as to the arrangement of atoms in molecules, and to complete them by introducing into molecular structure the conception of chemical energy. Who knows whether the contradiction displayed by argon will not be an impulse to the appearance of some epoch-making work on the structure of matter?†

II. HELIUM.

The researches were at this point in March last, when another far-reaching discovery was announced by Professor Ramsay. It being known that most metals and minerals absorb various gases which can be extracted from the metal or mineral, it was natural to inquire whether some minerals might not contain argon. This was done, and in the course of his investigations Professor Ramsay was brought to extract and to analyze the gas which is contained in a lately discovered mineral, cleveite, and which was said to be nitrogen. This gas contained a revelation. It proved to be argon, as Mr. Ramsay expected, but argon mixed with some other gas; this gas on spectroscopic examination displayed, among very many other lines, one bright yellow line which at once caught the attention of the explorers. It was not the well known yellow line of sodium, but was identified by Mr. Crookes as another line frequently seen in the spectrum of the sun's chromosphere, but never obtained before from any terrestrial object. This line, being very characteristic of the gases of the sun's atmosphere, was ascribed several years ago to some element unknown on the earth, but widely spread on the sun, which was therefore named helium. Now, this element was finally captured in a glass tube in the laboratory.‡

One can easily imagine the sensation produced by the announcement of this discovery. Many chemists had for years searched for helium among the substances which exist on the earth and in meteorites fallen from the celestial spaces, but in vain; while now the longed-for yellow line glittered in the spectroscope, quite unexpectedly, originating from a by-produce discovered in the search for argon! Upon the reception of the welcome news, the Upsala Professor Cleve (in whose honor Nordenskjold had named the mineral) at once extracted the new gases, and Thalen, one of the best spectroscopists of our time, fully confirmed Mr. Crookes' statement. The gas obtained at Upsala showed the same yellow line, but it contained no trace of argon; and Cleve at once ascertained that it was of a very low density. This was confirmed by subsequent experiments, and the last news from Upsala is to the effect that Cleve's helium was only 2·02 times the density of hydrogen, so that its atomic weight must be either four or two. The Upsala gas would thus come into the wide gap existing in our list of elements between hydrogen, whose atomic weight is taken for a unit, and lithium, whose atom is seven times heavier than the atom of hydrogen.§ On the other side, Mr. Lockyer has obtained the new gas by another method, from another mineral of the same group, broggerite; it was associated with hydrogen, but, like Cleve's gas, contained no argon. The same brilliant yellow line of helium shines in the spectrum of the broggerite gas, in company with several other lines which were known in the spectrum of the sun's chromosphere, but had never been seen before in the spectra of terrestrial objects.‖ It appears, moreover, from a second and third communication of Mr. Lockyer to the Royal Society ¶ that he has found traces of other solar gases mixed with helium, and that he expects to obtain by his method quite a series of gases, the spectral lines of which are associated with the spectral lines of the chromosphere.* At the same date we learned from Professor Ramsay that, while boiling cleveite in weak sulphuric acid, he obtained not only the gas supposed to be helium, but also argon devoid of some gas which is usually found in atmospheric argon, and which may be the cause of the high density of the latter. Three or four distinct gases have thus been discovered—or rather preliminarily pointed out by the spectroscope—while several more are already in view.

* Lord Rayleigh and Mr. Ramsay explain this last circumstance by the fact that in the manipulation of the gases large quantities of water were used, and water freely dissolves argon; to which Mendeleef very justly remarks that this is undoubtedly very possible, but has to be proved. See Lord Rayleigh's objections to this hypothesis in his Royal Institution lecture (Nature, June 13, 1895).

† It is well worth noticing that the case of argon is opposed to the case of chlorine, which is chemically a most active body, and also deviates from the law, but in an opposite direction. (See Mendeleeff's note on argon, l. c.)

‡ Communication made to the Chemical Society at its anniversary meeting (Nature, April 4, 1895, vol. li, p. 543, lii, p. 7; Proceedings of the Royal Society, April 25).

§ Mr. Ramsay found that his gas (obtained from a mixture with argon) has a density of 3·89, and the same monatomic structure as argon, or at least the same ratio of specific heats.

‖ Proceedings of the Royal Society, April 25, 1895; Nature, May 2, 1895, vol. lii, p. 8.

¶ Nature, May 10, 1895, vol. lii, p. 56.

We thus stand on the threshold of most important discoveries which are sure to throw much light on the

THE AFRICAN TRAVELER, ADOLF COUNT VON GOETZEN.

chemical processes going on on the surfaces of celestial bodies, and certainly will endow the physics of the sun and the stars with important generalizations; while on the other side the discovery of one or perhaps two gases, possessed of low atomic weights, which have hitherto been vainly sought for, will undoubtedly free our chemical classification from an incertitude which has prevailed till now. And, finally, the theoretical questions arising from the properties of argon, and even from the very errors which may have been made during the earlier hypothetical period of discussion, are sure to launch physics and chemistry in a new domain of philosophical speculation. This mass of discoveries, rapidly following each other, may seem bewildering; but they were not unexpected. For years chemistry had cautiously perfected its methods, and minutely accumulated new data in a limited circle of facts. Now, the fruits of that laborious work are rapidly ripening. "Are we facing a new period in chemistry?" Cleve exclaimed at the end of a letter in which he announced his discovery. Undoubtedly we are entering a period when both our knowledge of facts and our theoretical views in chemistry will be immensely widened.

* The fact of several chromosphere lines being seen at the same time is the more important, as Professor C. Runge, armed with one of the best spectroscopes, maintains (in a letter dated May 16, and published in Nature, June 6, 1895) that the yellow line obtained from cleveite is not at all the helium line, but consists of two lines situated on both sides of the latter. Up to this date (June 19) the contradiction between such authorities in spectroscopy as Runge, Crookes, Lockyer, and Thalen has not been explained in the press; but the concurrent appearance of several chromospheric lines leaves little doubt as to the discovery of gases which prevail in the atmosphere of the sun.

(To be continued.)

COUNT VON GOETZEN'S JOURNEY THROUGH CENTRAL AFRICA.

COUNT VON GOETZEN started in December, 1893, on a bold journey through Central Africa from east to west, and when he returned about a year later his geographical discoveries at once made a great name for him in the scientific world; so that all are interested to know something of his life. He was born May 12, 1866, at Castle Sharfeneck, in Silesia, and attended the Schnepfenthal school in Thuringia. Later he studied law. In 1887 he was made second lieutenant of the second Uhlan Guard, to which he still belongs. When he was sent, in 1890, to join the embassy at Rome, he conceived the idea of a hunting expedition to Kilimandscharo, and in the summer of 1891 he went, accompanied by Dr. Ehrhardt, from Tanga to the Umba River, along Mts. Usambara and Ugueno to Moschi, and then turned back toward Pangani. Soon after his return Count von Goetzen was ordered to the military academy, but he could not endure a long sojourn in Europe, and in the autumn of 1893 he went to Africa again, this time accompanied by Assessor von Prittwitz and Gaffron, also from Silesia and lieutenant of the reserve of the second Uhlan Guard, and Dr. Hermann Kersting. The object of the expedition was to explore the watershed between the Congo and the Nile and to obtain information in regard to the active volcanoes in Central Africa, of which no very definite reports had reached us. They went from Pangani over Irango to Usukuma and then stayed for some time at Ushiromba, the station of the "White Fathers," south of Victoria Nyanza, where they had a warm reception and had an opportunity of observing the work of the missionaries. The Wangoni, who have settled near the mission, have pushed farther northward than any of the other tribes that are related to the Zulus.

Like the Massai, they lived by pillage, and finally made a treaty with the Unyamwesi chiefs, with whom they made war on the neighboring tribes, laying the land waste and rendering the commercial highways unsafe. Lieutenant Langheld conquered them several times, and now they give no trouble in the neighborhood of the mission. They sent a delegation to visit the travelers and carry them a present of leopard skins. From there the expedition turned northwestward, toward the more populous Ruanda and the most westerly of the range of volcanoes, over which a bright light was visible every night, to Kirunga tsha Gongo (in English, Place of Sacrifice). It took six days to climb

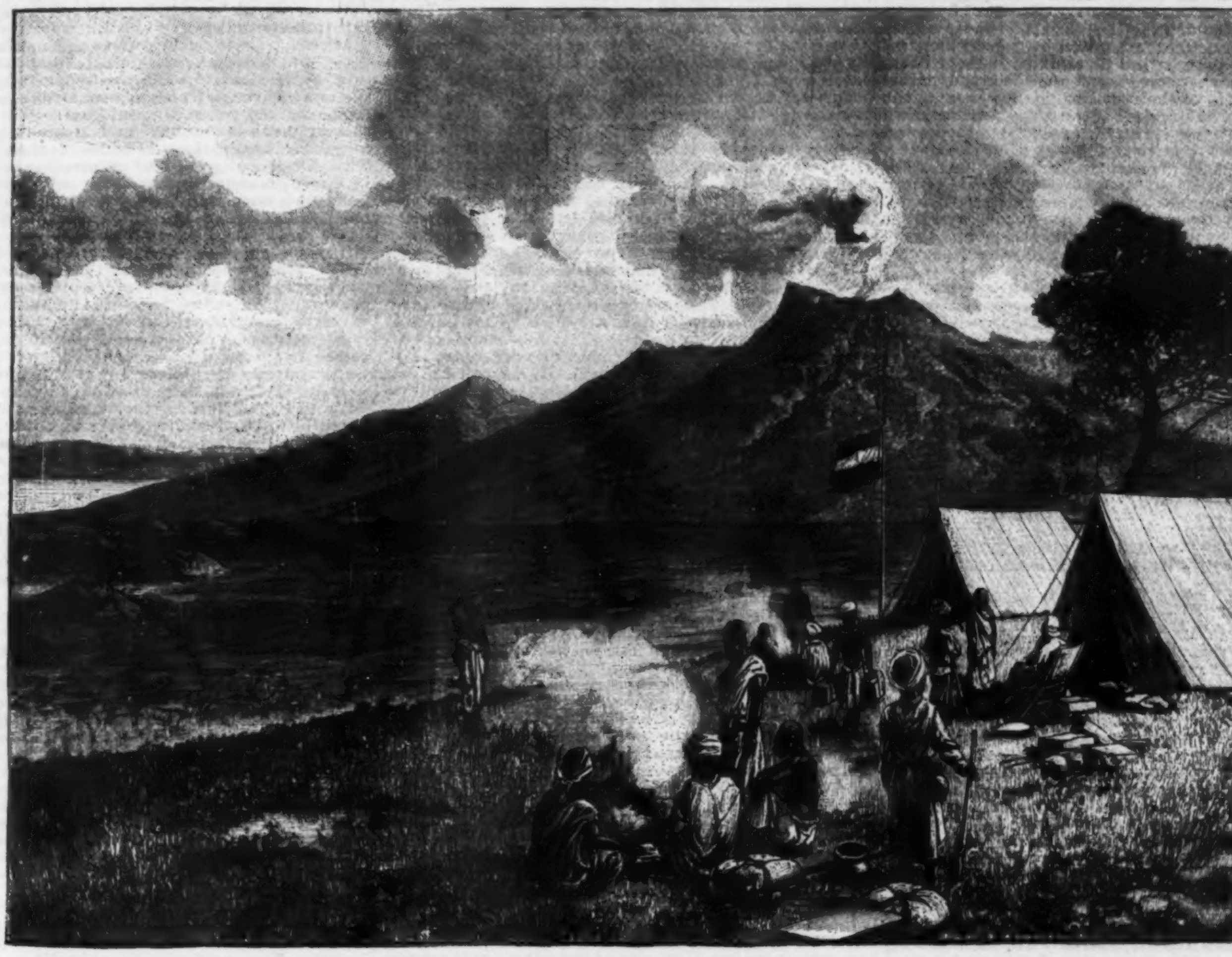
WANGONI WARRIORS.

the mountain, four days being consumed in cutting a passable path.

This mountain is shaped like a pyramid with the top cut off, and it is overgrown to a height of 9,184 ft. with erica, everlasting and low bushes. The summit of the mountain, which is about 10,990 ft. high, is an immense funnel-like crater about a mile in diameter, with walls 280 ft. high, which are almost perpendicular on the inside, and at the foot of which stretches the smooth cement-like surface of a cooled sea of lava. To quote the words of the traveler, "Standing on the edge of the crater, one overlooks a gigantic arena with steep, high walls; below is a perfectly level floor of a yellowish brown color, and in this floor are two openings, as regular as if made by human hands.

"The more northerly of the openings is from 350 ft. to 500 ft. in diameter, and from it reddish smoke issues at regular intervals, accompanied by a noise like thunder. On the western edge there is another eruption opening, and later, at a distance of about seven miles, another opening was found from which lava was flowing. Very near to Kirunga lies the steep Navunga and the pointed cone of Kausumbi. The mighty Kisigali, the low, picturesque Wihanga with its sunken craters, and the eastern pillar of the Kirunga range, Msumbiro, were not visible from there." All of the mountains, with the exception of Wihanga, are probably more than 13,100 ft. high. It must have been a grand landscape that unrolled itself before the eyes of the spectators.

From the foot of Kirunga tsha Gongo, Lake Kivu stretches to the south, from which the Rusisi flows into the Tanganyika. It is about 5,000 ft. above the



FROM COUNT VON GOETZEN'S JOURNEY ACROSS CENTRAL AFRICA: KIRUNGA TSHA GONGO FROM THE LAVA PLAIN, AND THE CAMP OF THE EXPEDITION.—DRAWN BY R. HELLGREWE, FROM A PHOTOGRAPH.

THE PRINCIPAL CRATER OF KIRUNGA.—DRAWN BY R HELLGREWE, FROM SKETCHES AND PHOTOGRAPHS.

level of the sea, and it cannot be much smaller than Lake Albert Edward, for in spite of the clear atmosphere nothing could be seen of the southern and western banks from the northern point, and a very heavy surf broke on the lava rocks. Lake Kivu is very like the lakes of northern Italy. An archipelago of beautiful little islands, mostly uninhabited, made it easy to go about on the lake in small boats, and as there was no lack of food, the stay on the lake was a real summer holiday for the travelers. But they had to endure the greatest hardship on the march that followed; the region had been pillaged by the slave hunters, the paths were overgrown, and the incessant climbing up and down in the mountainous country was most fatiguing.

July 20 they reached the border of the forest, which disappointed the Europeans, whose expectations had been raised too high by the fanciful accounts of Stanley, but where the swamp was not knee deep the marching was easy, for the underbrush did not grow in the deep shade. On August 17, the expedition started across the charming Lowa, which is very deep and about 330 ft. broad, and on the 21st they reached a great settlement of Wasuaheli and Manyema. On the 27th they camped on the Oso, a beautiful tributary of the river just referred to, which is about 980 ft. broad. From that time to Sept. 10, the date of their arrival at Luvuto, there was great suffering and about thirty died from hunger, exhaustion and poisoning from wild fruits.

But with their arrival at Luvuto all suffering was ended. A Belgian officer came out to meet the expedition, and on Sept. 21 Count Goetzen entered Kirundu, on the Congo, which is often erroneously called Kibonga. It is worthy of note that the objects of the expedition were accomplished in a most peaceable manner, and that the Europeans enjoyed excellent health during the long journey, the result of a careful diet.—Illustrirte Zeitung.

THE RELATION BETWEEN THE MOVEMENTS OF THE EYES AND THE MOVEMENTS OF THE HEAD.*

Delivered before the Oxford University Junior Scientific Club at the University Museum, Oxford, on May 13, 1895.

By A. CRUM BROWN, M.D. Edin., F.R.S., Professor of Chemistry in the University of Edinburgh.

WE all know that it was a long time before mankind found out that the earth moves. For ages the apparent motion of the heavenly bodies was supposed to be their real motion, the earth being fixed. We who know something of the truth in this matter, do not, however, any more than our ancestors did, see or feel the earth move. We believe that it does so, either because we have been told by some one who, we think, knows about such things, or because we have reasoned the matter out from data observed by ourselves or reported by credible observers. But in habitual thought and speech we go back to the old assumption, which, for our practical, terrestrial purposes, answers well enough and is perfectly in accordance with our sensations.

When we turn from the great cosmos to the microcosm, when we compare the motion of our own body among the various fixed (terrestrially fixed) and moving bodies around us with the motion of the earth among the stars, we find quite a different state of matters. It never occurs to us that our own body is at rest and that the trees, houses, etc., move. When we really move we not only know but feel and see that we are moving, and every one, learned or ignorant, old or young—if only he is sober—feels and sees that the solid earth is fixed, except on the rare occasion of an earthquake and in the case of some illusions which we shall have to consider. I wish to discuss the cause of this sensation of the fixedness of the earth, and also incidentally of the exception implied in the words I have just used, "if only he is sober." If we keep our head fixed and look at any really fixed scene—say, a room in which there is nothing moving, or a landscape, if we can find one, without railway trains, ships, moving beasts, or flying birds—we can allow our eyes to run over it in as uniform or as irregular a way as we please, and see that the scene remains fixed. We might have supposed that as we move our eyes from right to left the whole scene, like a moving panorama, would seem to move from left to right, but it does not do so. It remains visibly at rest, and we know, without any reasoning about it, that the changes of view were produced by the motion of our eyes.

We fancy that we can move our eyes uniformly, that by a continuous motion like that of a telescope we can move our eyes along the sky line in the landscape or the cornice of the room, but we are wrong in this. However determinedly we try to do so, what actually happens is that our eyes move like the seconds hand of a watch—a jerk and a little pause, another jerk, and so on, only our eyes are not so regular—the jerks are sometimes of greater, sometimes of less, angular amount and the pauses vary in duration, although, unless we make an effort, they are always short. During the jerks we practically do not see at all, so that we have before us, not a moving panorama, but a series of fixed pictures of the same fixed things, which succeed one another rapidly. It is not difficult to understand how this gives rise to a sensation of the fixedness of the eternal scene. If, in the otherwise fixed scene, there is a really moving object, we see it move, because during the pauses, short as they are, the moving object has visibly changed its place, and in each of our fixed pictures the moving object is seen to move. If it moves too slowly for this, then we do not see it move, but only infer its motion from comparison of its position at different times. If we keep our eyes fixed on the moving object—and this is possible if it does not move too fast or too irregularly—then we see it fixed and the really fixed things moving, an illusion we have all observed when the pier seems to move and the steamer remain at rest. That the eyes jerk in the way now stated can be made plain by means of a simple experiment.

If we have in the field of view a bright object, such as an incandescent electric lamp, and after running our eyes over the scene before us, shut our eyes, we see secondary images of the bright object.* Now if the eyes move continuously from one position to another, we should see between the two secondary images of the bright object corresponding to these two positions a bright band composed of an infinite number of images each infinitely near its two neighbors. But we see no such band, but a finite number of sharp individual images, each of which corresponds to the position of the eyes during a pause between jerks; unless the bright object is very bright, there is nothing in the secondary image to represent the positions of the eyes during the jerk.

If for a bright object we take the sun, then we do see bands joining the sharp secondary images. These bands are fainter than the sharp images and die away sooner. They are the impressions made on the retina by the image of the sun passing rapidly across it during the jerk; but if with the fixed bright object in the field we follow with our eyes a really moving thing, then on shutting the eyes we see a band of light, because the image of the bright object passed not very rapidly across the retina. This habit of jerking the eyes from one position of vision to another as fast as the light, well-poised globes can be swung round by the quick-working, straight-fibered muscles which move them may be an innate habit or it may have been acquired by our looking at things and turning quickly from one object of interest to another; at all events, it is now the way in which alone we can move them unless we fix them on a moving object.

So far I have supposed the head fixed and the eyes alone moving. Let us now attend to what happens when we move our heads.† The movement of the head, unless it is very rapid, makes no difference at all in the phenomena just described. If we call the line along which we look during the pause between two jerks a glance line, we may describe the whole phenomenon by saying that the glance lines are fixed relatively to fixed external objects, whether the head is rotated or not. This, of course, means that during a pause the eyes are rotated relatively to the head about the axis on which the head is really rotated, in the opposite sense and through the same angle as the head. It might be supposed, for all that has yet been said, that this fixedness of the glance lines when the head is rotated depends on the habit of looking at things, but that this is not the cause, or, at all events, not the only cause, is plain from the fact that the same relative movements of the eyes take place when we look at an objectless field of view, such as the clear, cloudless sky, or, as was, I believe, first noticed by Dr. Breuer, when the eyes are shut. By placing the fingers lightly over the closed eyelids we can feel the motion of the prominent cornea. If, with eyes shut and fingers so placed on the eyelids, we turn the head or turn the head and body round, we feel the eyes twitch.

As the head turns round, the eyes retain for a little a fixed orientation in respect to external fixed things and then jerk so as to make up for lost time, again pause and again jerk, and so on; so that, while the head turns uniformly, the eyes, which must, of course, on the whole make one full turn while the head makes one full turn, do their rotation intermittently, being, so to speak, left behind by the head and then making up by a rapid jerk. Another proof that these compensatory movements, as they may be called, of the eyeballs are not, or at least not wholly, caused by the effort of looking at things, is afforded by observing what happens when the head is rotated about a fore and aft axis, about an axis coinciding with a glance line. If we keep our eyes fixed on a particular point and rotate the head about the line along which we look,‡ we still see things fixed, the world does not seem to revolve about our fore and aft axis. Here, also, we can show by means of secondary images that we see a series of fixed pictures.

If, with a bright object in the field of vision, we fix our eyes and keep them fixed on a point about 15° distant from the bright object (if we keep both eyes open, about as far from our eyes as the bright is, so as to avoid double vision), and then rotate the head about a fore and aft axis through say 30° by inclining the head toward one shoulder, and shut the eyes after this performance, we see a number of sharp secondary images of the bright object arranged upon an arc of a circle the radius of which is the angular distance of the bright object from the point fixed. If I have rotated my head through about 30°, I see about five secondary images, so that what I call the angle of rotatory nystagmus is, in my case, about 6°. Here we have been looking all the time at the same point, and it is not easy to suppose that the very slight attention we pay to objects seen indirectly, or, as we sometimes say, "with the tail of the eye," could lead to a habit, so fixed that we cannot escape it, of moving the eyeballs in the way described.

I have said that the movement of the head, unless it is very rapid, does not affect the fixedness of the glance lines. Translatory motion of our body may be so rapid, as in a railway train, that the eyes cannot twitch so fast as to keep the glance lines fixed relatively to near fixed objects. The eyes do their best; they twitch, but not enough, unless the train is moving slowly, and near objects seem to fly backward. We succeed with fixed objects at a greater distance from us; we can see them fixed, and all objects between us and such visibly fixed objects are seen to move backward, and fixed things beyond them seem to move forward with us. Of course, if by keeping our attention on our carriage and its contents our glance lines become fixed in reference to these really moving things, they seem fixed, and the whole world outside of the carriage is seen to move in the direction opposite to that of our real motion.

It is also obvious that rotation of the head, if it is more rapid than the quickest possible rotation of the eyeball in the head, must affect the position of a glance line, for, in order that the glance line may remain fixed, the eyeball must rotate in reference to the head as fast in one sense as the head rotates in reference to external things in the other sense; but in the case supposed the eyeball cannot do so.

We can try this experiment without having recourse to mechanical means of rotating our body and head, which of course we can do as fast as we please, and a great deal faster than is either pleasant or safe. The most rapid rotation of our head which we are able to produce by the direct action of our muscles is what is known as "wagging"—that is, a rotation about a vertical axis upon the joint between the first two vertebræ. In this way it is possible to give the head an angular velocity considerably greater than the maximum angular velocity of the eyeball. When we do this as fast as we can we see that external things do not appear steady. When we wag our head to the right we see the world wag to the left, and vice versa. But the external really fixed things do not appear to us to describe nearly so large an angle as the head really does; the eyes make an effort to compensate the rotation of the head—an effort only partially successful, the angle through which external things seem to move being the difference between the actual angular rate of movement of the head and the maximum possible angular rate of movement of the eyeball in its socket. This difference can best be observed—and, indeed, can be approximately measured—by observing a distant light on a dark night while we wag the head. The point of light seems drawn out into a horizontal line of light, the apparent length of which is the angular difference in question. As we can wag our head much faster than we can nod it, the apparent length of the vertical line of light into which a bright point is drawn out when we look at it and nod as rapidly as we can is much less than that of the horizontal line of light just spoken of; but I find that I can, by nodding, rotate my head about a right and left axis a little faster than I can rotate my eyes about the same axis, so that the luminous point does appear to be drawn out into a short vertical line. Such violent movements of the head occur sometimes in our ordinary (not experimental) use of our eyes, but they are rare and isolated, so that the disturbance of the fixedness of the glance lines which they cause does not really affect our sense of the fixedness of the world. The illusion of the moving pier and fixed steamer (which we have all also observed when there is a train alongside that in which we happen to be, and we see the moving train fixed and the fixed train moving) is corrected by looking at the shore or the railway station. For a moment these also seem to move, but our glance lines almost instantly become fixed in reference to those things which we know are fixed, and it is then difficult to recall the illusion. Another similar case is that of the moon and the clouds. We sometimes see the moon moving and the clouds fixed, sometimes the clouds moving and the moon fixed, as our glance lines are fixed relatively to the clouds or to the moon, and a little practice enables us to change from the one sensation to the other at will.

What has been said seems to show that our immediate sense that the earth and what we call fixed objects on it are fixed is a consequence of the way in which we move our eyes, and in particular, of the way in which, by a suitable movement of the eyeballs, we involuntarily and unconsciously compensate movements of the head, voluntary or involuntary, conscious or unconscious.* That such an immediate sense of the fixedness of external fixed things is of great use to us in moving about among them is plainly shown when we observe the trouble which a drunken man, who has lost this sense, has in guiding himself.

I now turn to the question, What is the cause of this prompt and wonderfully accurate compensatory movement of the eyeballs? There are three sources from which we can obtain information leading to an answer—viz., 1, from experiments on ourselves; 2, from anatomical observations and measurements; and 3, from observations of the effects of injuries to the labyrinth of the internal ear. I shall consider these in their order.

By experiments on ourselves I mean the study of the effect on the motion of the eyes and on our sense of the fixedness of external things, of movements of our head (in this case always along with the rest of our body), which we do not make, as a rule, for any other purpose. I have already stated that if we shut our eyes, place our fingers on the eyelids, and turn round about a vertical axis, we feel with our fingers the jerking motion of the eyeballs. If, instead of turning round once, we turn round several times—still better, if we seat ourselves on a turning table and get someone else to turn it and us round at a uniform rate—we find that the jerks become less and less frequent, and after two or three turns cease altogether. Another thing which we observe is that, although the turntable is being turned round at a perfectly uniform rate, we feel the rotation becoming slower and slower, and when the jerks of the eyeballs have quite ceased we feel ourselves at rest and have no sensation of rotation. Let us for convenience call the sense in which the rotation is still going on positive. This uniform positive rotation has become to us imperceptible (as long as we keep our head in the same position in respect to the vertical), and is what we may call a "new zero of rotation." If the rate of rotation is now increased, we feel this increase as a positive rotation; if it is diminished, we feel the diminution as a negative rotation—a rotation the other way about. What we really perceive then is acceleration of rotation, using the word "acceleration" in its technical sense. If the turntable is stopped, this is a negative acceleration, and what we feel is that we are being turned round in the negative sense, and at the same time we feel our eyeballs jerk. The sense of rotation and the jerking die away in this as in the former case. If, while we are being turned round with uniform angular velocity, but after all sense of rotation and all jerking of the eyeballs have ceased, we open our eyes, we still feel ourselves quite at rest, but we see all external objects turning round us; as has been well said by Professor Mach, the external world seems to turn round inside an outer, unseen, fixed world.

It is in reference to this imaginary fixed world that our glance lines are now fixed. If the rate of rotation is changed while the eyes are open, the sensation of rotation is exactly the same as if they were shut; we feel the acceleration—positive or negative—as a rotation in the one or in the other sense, and the jerks of

* Being the fourth "Robert Boyle" lecture.—From the London Lancet.

* The secondary images are better seen if we look at a white surface and wink rapidly.

† By "moving the head" I mean moving the head either alone or along with the body or any part of it.

‡ If we take a sufficiently distant object as the thing to be looked at we may neglect the want of coincidence of the two glance lines belonging to the two eyes, and, moreover, all that is here described is seen as well, though not so conveniently, with one eye shut.

* I need hardly repeat that by movements of the head I mean movements of the head whether accompanied or not by movements of the body.

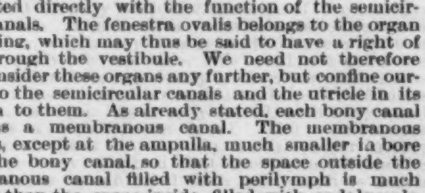
the eyeballs take place as if the real external world were not there and we were looking beyond it at the unseen fixed world outside of it—that imaginary world in reference to which our glance lines are now fixed. If, while the experiment I have described is going on, we move so as to change the direction in our head of the axis of rotation—for instance, if after uniform rotation about a vertical axis has gone on, with the head in its usual upright position, until the sense of rotation has ceased, we bow our head forward so that the axis of rotation is now parallel to a line from the occiput to the chin—a very striking and somewhat alarming, but most instructive, sensation is experienced. What we feel is that we are being turned round with a rotation which is the resultant of two rotations of equal angular velocity—one the real rotation about what is now the vertical, the other the imaginary (but equally perceived) rotation in the opposite sense, about the line in the head which was vertical. If the angular movement of the head is small, so that the angle between what is the vertical and what was the vertical is small, then the two component rotations nearly neutralize one another and the strange and alarming resultant is slight; but if the head is bent so that the old and new verticals are at right angles to one another, the real and imaginary components are both felt in full, and the effect is very startling. If the rate of rotation is changed simultaneously with the change of position of the head, we have a resultant of two rotations of different angular velocity.

The most easily observed case of this kind is when the rotation is stopped altogether at the moment of change of position of the head. Here the real component is zero and we have only the imaginary one. This is the case of the well-known practical joke. A man is asked to plant the poker before him on the floor, place his forehead on the end of it, walk round it three times, and then rise and walk to the door. The preliminary part of this experiment presents no difficulty; the victim plants the poker, puts his forehead on it, and walks round it with the greatest ease and with no sense of anything unusual; but when he rises the line in his head which was vertical is now horizontal, and he feels himself turned round about that horizontal line. The external world he also sees turning round this line, objects on the one side rising up and objects on the other side sinking down. In this visibly swaying world he has to guide his sensibly rotating body, and if his friends do not catch hold of him he is pretty sure to fall. All these experiments are most conveniently made on a smoothly working turntable of such a size that one can comfortably lie down upon it.

By the kindness of Messrs Dove, lighthouse engineers, I had the use of a large turntable made for the revolving lantern of a lighthouse. It could be turned round smoothly and uniformly at the moderate speed that is most suitable for experiments of the kind in question. A few experiments with such an apparatus will convince any one that we have here to do with a perfectly definite sense and not with any vague sensations caused by the inertia of the soft parts of the body. This is one of the ways in which the phenomena have been explained by those who hesitate to believe that there can be a definite special sense only discovered within the last few years. That the origin of the sensation is not in the soft parts of the body generally, but in the head, is made perfectly plain by the fact that the position of the head and the changes of that position alone determine the sensations. We must therefore look in the head for the organ of this sense.

In close proximity to the cochlea, which is universally regarded as the organ of hearing, there is an organ of very striking and, I might say, mysterious form. It is found in all vertebrates, and occurs in them fully developed except in the lowest forms of fish. It is contained in a bony—in cartilaginous fishes in a cartilaginous—cavity which communicates in birds and mammals with the cochlea or lagena. This cavity may be divided into the vestibule and the three semicircular canals. The canals open at both ends into the vestibule and each has at one end an enlargement called the ampulla.* Within this bony case is contained a membranous structure consisting of the utricle, situated in the vestibule, and three membranous canals, each in one of the bony canals, each with an ampulla in the bony ampulla, and each opening at both ends into the utricle. The vestibule contains, besides the utricle, the saccule, a membranous bag continuous with the cochlear duct, and has in the side next the tympanic cavity a hole in the bony wall filled in by a membrane and known as the fenestra ovalis. The saccule and the utricle have each a spot on the lower wall supplied with nerves which end in air cells known as the macula acustica.

The maculæ acusticæ are probably, as suggested by Professor Mach and Dr. Breuer, organs fitted to perceive acceleration of translatory motion, and are not connected directly with the function of the semicircular canals. The fenestra ovalis belongs to the organ of hearing, which may thus be said to have a right of way through the vestibule. We need not therefore here consider these organs any further, but confine ourselves to the semicircular canals and the utricle in its relation to them. As already stated, each bony canal contains a membranous canal. The membranous canal is, except at the ampulla, much smaller in bore than the bony canal, so that the space outside the membranous canal filled with perilymph is much greater than the space inside filled with endolymph. The membranous ampulla much more nearly fills the bony ampulla, so that here the perilymph space is comparatively small. The membranous canal is



pretty firmly attached (in some animals, at all events) to the periosteum of the bony canal. (See diagram.)

* In all animals the non-ampullary ends of the superior and the posterior canal have a common opening into the vestibule.

Each canal is, in all animals I have examined, approximately in a plane, and it is important to consider the relations of these planes to one another and to the mesial plane of the head. As I have brought part of the apparatus with me, I may shortly describe the method I used to measure the angles which these planes make with one another, and also an improved method of which I have not yet had time to make any very full trial.* It consists in attaching the preparation—either a cast of the canals, or in the case of a bird the dissected and cleaned bony canals—to one arm of a branched rod, and a lump of wax to the other. The rod is then fixed to the large apparatus already referred to. The canals are successively made horizontal, and a small plate of glass is fixed horizontally in each case—parallel, therefore, to each canal—to the lump of wax. We can also attach a glass plate parallel to the mesial plane. We can thus have, on a comparatively small piece of wax, glass plates parallel to all the planes the relations of which to one another are to be measured. The lump of wax is then removed from the rod, and the angles between the planes of the glass plates are measured by means of an ordinary reflection goniometer. The general results are: 1. The canals do not lie rigorously in planes, but sufficiently nearly so to give closely accordant results. 2. The external canals are very nearly at right angles to the mesial plane, and, therefore, from the bilateral symmetry the two external canals are very nearly in one plane. 3. The superior and posterior canals of the same side make approximately equal angles with the mesial plane. In all cases which I have examined the angle between the posterior canal and the mesial plane is somewhat larger than that between the superior canal and the mesial plane. From the bilateral symmetry, therefore, the superior canal of the one side is nearly but not quite parallel to the posterior canal of the other side.

In the discussion of the way in which the system of canals may be supposed to act I shall for convenience assume that these canals are parallel, as the deviation from exact parallelism only complicates, but does not at all vitiate, the argument. 4. In man and in a large number of other animals, the three canals are very nearly at right angles to one another; but in a good many of the animals I have looked at the superior and posterior canals make with one another an angle considerably greater than a right angle. Looking at the six canals as forming one system, we see that we have three axes and that at right angles to each axis there are two canals, one internal, the other external—these two canals having their ampullæ at opposite ends, so that if rotation takes place about the axis, the ampulla in the one case precedes the canal and in the other follows it. The vertical axis, as we may call that at right angles to the two external (or horizontal) canals, is pretty nearly vertical in most animals in the usual position of the head when the animal looks to the horizon; in man it is not exactly so—we must bow our head a little to make this axis vertical. If we suppose that we are looking north, the other two axes are N. E. and S. W. and N. W. and S. E. respectively. In man they pass from the eye of one side to the mastoid process of the other side, and are nearly at right angles to one another. As already stated, in some animals they are inclined and are nearer the right and left than the fore and aft line in the head.

In order to see how such a system can work as a hydrodynamical instrument let us first consider one canal. Here we have two watery liquids: the endolymph within the membranous canal, its ampulla and the utricle; and the perilymph between these and the bony case. How will these behave when rotation takes place about an axis normal to the plane of the canal? The inertia of the liquids will tend to produce a flow through the canal in the sense opposite to that of the rotation. Let the rotation take place so that the ampulla precedes the canal. Here the endolymph will tend to flow from the utricle into the ampulla, and thence through the canal to the utricle again. But, as Professor Mach has pointed out, the canal has too small a bore to allow of any sensible flow through it, so that the effect of this rotation will be to increase the pressure within the membranous ampulla. But—and this is a point to which, as far as I know, no one has hitherto called attention—as there will also be a tendency of the perilymph to circulate, so in its circle there is also a narrow place—namely, at the ampulla; for as the membranous ampulla nearly fills its bony case there is not much room there for the perilymph to pass from the vestibule into the space surrounding the membranous canal.

There will, therefore, be a diminution of pressure of perilymph at the ampullary end of the canal, so that the ampullary walls will be stretched by the increase of pressure within and the diminution of pressure without. Of course, when the rotation is kept up uniformly for some time the pressure inside and outside of the membranous ampulla is soon equalized and the stretching or relaxation ceases. With the cessation of the stretching the sensation must also cease. If now the rotation is stopped, the perilymph and endolymph will tend to move on, and pressure will be produced inside the membranous ampulla of that canal which during the rotation moved with the ampula following the canal. All this will, of course, be reversed when the rotation takes place with the ampulla following the canal; the pressure inside the membranous ampulla will be diminished, that without will be increased, and the walls will become flaccid. In each membranous ampulla there is a so-called "crista acustica" where nerves terminate in hair cells, and it is not difficult to suppose that stretching of the ampullary walls will irritate these nerve endings while a relaxation of the ampullary walls will produce no irritation. If this be so, then we have three axes, each with an organ sensitive to rotation about it in either sense and capable of discriminating between the two; and as every rotation of the head can be resolved into component rotations about these three axes we have the means of perceiving the axis and what we may call the "intensity" of the rotation, or perhaps more correctly the "rotational acceleration."

This hydro-kinetic theory of the function of the semicircular canals was propounded at very nearly the same time by Professor Mach, of Prague, Dr. Breuer, of Vienna, and myself. I give the names in the order of publication. The views expressed by us were not exactly the same, and the statement of the theory I have just given is any one of them with additions and corrections from the other two. I have not thought it necessary to refer to the hydrostatic theory of Goltz, or, indeed, to give any details of the literature of the subject. A very full and accurate digest of almost everything that has been written on the functions of the several parts of the labyrinth of the ear has been published in Russian by Dr. Stanislaus von Stein and translated into German by Dr. C. von Krzywicki. The theory as I have just described it might perhaps have been developed, as I have here developed it, from a consideration of the structure and position of the canals; but, as a matter of fact, this was not the historical order. It was the experiments of M. Flourens that first directed attention to these organs as having something to do with the equilibrium of the body. In reference to these experiments and those made since by many able physiologists and skilled operators, I shall only say that the results seem to me to be consistent with the hydro-kinetic theory. Certain of M. de Cyon's experiments, in which he increased the pressure in the canals by inserting in them small tangle plugs without producing any nystagmus or rotatory movements of the head, appear to contradict the theory; but increase of pressure in the bony canal can have no tendency to stretch the walls of the membranous ampulla, and therefore could not be expected—if the theory as I have stated it is correct—to produce a sensation of rotation; what is required is that the pressure inside the membranous ampulla should be greater than that outside of it. The symptoms observed in cases of disease of that internal ear also appear to support this hydro-kinetic theory. But the position of the canals in close anatomical relation to the organ of hearing had impressed on the minds of physiologists so obstinate an opinion that they must be connected with the perception of sound in some way or other that even now many will not admit that they are the peripheral organs of a sense of rotation.

A favorite theory was (and there are still some who hold it) that the semicircular canals give us information as to the direction in which sound comes to us. There are two ways in which we can show that this view is erroneous: 1. By considering the physical conditions. The shortest sound wave which we can hear is so long compared with the dimension of the ear that every part of the ear must be at any instant in the same phase of the wave. We must assume that, as far as the effect of such sound waves is concerned, the liquid contents of the internal ear are incompressible. It is as absurd to speak of sound waves traveling round one of the canals as to say that it is high water at one end of a dock and low water at the other at the same time. 2. By experiments on the way in which we really do perceive the direction of sound. I shall describe two such experiments: (a) Let the observer close his eyes—for security it is best to bandage them—seat himself in a chair, and keep his head steady. Now let an assistant produce a sharp short sound. In showing this experiment to the Biological Section of the British Association at its meeting at Belfast in 1874 I used three coins in the way I show you now. The observer can tell with really astonishing accuracy whether the sound comes from the right or from the left, because he hears it louder in the nearer ear, but he is without any knowledge at all as to whether it comes from above or below, from the front or the back. He forms a judgment, indeed, on this point, but this judgment is usually wrong, often very ludicrously so. The experiment is most striking when the click is produced in the mesial plane of his head, in which case he has not the binaural effect to help him. In this connection I may say that I know no experiment which illustrates so well the marvelous delicacy of our sense of relative loudness of sound, a very small deviation from the mesial plane being quite certainly recognized. We have, then, with one ear no means of ascertaining the direction of sound if we keep the head fixed. How, then, do we ascertain the direction of sound, for we all know that we can do so with very considerable accuracy? This leads me to the second experiment. (b) Let the observer, still with eyes closed and bandaged, stand up and be at liberty to move his head. Let the assistant produce the clicking sound—not once only, but again and again at short intervals, always in the same place. The observer turns round until he faces the source of the sound. He knows that he is facing it when he hears it equally loud in both ears, and hears it to the right when he turns a little to the left, and to the left when he turns a little to the right—that is the criterion of whether the source is behind or before him. Having now got the azimuth, he seeks the altitude. Moving his head about a right and left axis, he seeks the position in which he hears the sound best. He is now looking toward the source of the sound.

The concha of the external ear acts as a screen, and it is remarkable how much difference there is in the quality as well as in the loudness of most sounds with different altitudes. Stand in front of a pipe from which water is rushing and move the head round a right and left axis—bow, in fact, to the pipe—and a striking difference in the quality and loudness of the sound will be observed in the different positions of the head. It may be said that birds have no concha, and yet they perceive as well as we do the direction of sound. But there is a method by which, without any use of the action of the concha and by purely binaural observations, we can ascertain the direction of sound. By one observation, as already described, we can find a plane containing the line along which the sound reaches us. That plane is at right angles to the line joining our two ears. By moving the head we can shift the line joining our two ears, and then by another similar observation obtain the plane at right angles to the new position of the line joining the two ears and containing the direction of sound. The direction of sound is the intersection of these two planes. I do not think we use this method (although I have tried it and found it work), but we often see birds when listening incline their heads in such a way as to suggest that they use it.

There is another objection which is often brought against the theory I have been explaining. It is said, "Is it conceivable that there should be a special sense,

* The method illustrated by the human skull shown is fully described, with wood cuts from photographs, in Professor McKendrick's Text-book of Physiology, vol. ii, pp. 697-699, and therefore need not be reprinted here. The other method will, I hope, give more accurate measurements.

common to man and all vertebrate animals, which has remained unknown till about twenty-two years ago? This is a sense invented, not discovered, by scientific men, otherwise we should all have known about its existence at least." This objection is not one to be met by contempt; it has a real basis, and as I believe this sense to be a real one, I feel bound to look for the cause of the incredulity. A special sense is popularly understood to be a gateway of knowledge. Information as to external things comes to us in various ways, and each of these ways has from ancient time been recognized and named as a special sense; but this is not exactly the physiological way of looking at things. I may illustrate the difference by a sort of analogy. In a large business establishment the manager sits in his room upstairs. He has various ways of getting information. The post brings him letters; he looks at them—some he carefully considers and answers, others he looks at and puts into the waste paper basket, but he has looked at them all. So we see things. Many of the things we consider, take note of; others we pay no attention to, do not an hour later remember anything about them. But there are many messages which come to the business establishment and never reach the manager's room at all; they are attended to by clerks in the office. They are not futile, they are real messages and serve their purpose, a purpose essential to the carrying on of the business. If these were not attended to downstairs, the manager would very soon hear of it. So with us. There are what we may call sensory impressions which do not make their way to the conscious ego, but are all the same properly attended to by what in us corresponds to the clerks. If our clerks neglect their work the conscious ego very soon becomes aware that there is something wrong. In the case of the sense of rotation ordinarily we pay no attention to its messages; the clerks at the sensory centers of the ampullary nerves and at the motor centers of the muscles of the eyeballs do all that is necessary. We perceive the result of their work in our visual sense of the fixedness of the outside world, and we do not trouble ourselves as to how the office work has been done; but—and here I come to a matter I referred to early in this lecture—the office work is sometimes not well done, and the visual sense of the fixedness of the outside world is lost. If this is due to disease, we send for a medical man and ask him to find out what is wrong in the office and, if he can, put it right. But there is a far more common cause of the loss of the visual sense of the fixedness of the outside world—one which it has not been left for two or three scientific men to discover in the last quarter of the nineteenth century. The most characteristic effect of alcohol is to make all reflex actions sluggish. Under the influence of a moderate dose of alcohol, what I have called the "office work" goes on all right, but not quite so fast as with no alcohol. The message arrives and the answer is sent, but not quite so promptly. The conscious ego may not note anything wrong, but a quantity of alcohol (far short of a dangerously poisonous dose) may delay the transmission of the signal to the muscles of the eyeball so much as to affect quite perceptibly the compensation of the movements of the head. A perfectly sober man sees the world wag a little when he wags his head very vigorously—a point of light is perceptibly drawn out into a horizontal line of light; the office work fails a little under such extreme pressure. But a little alcohol makes the office work fail more readily, and as the dose is increased it fails altogether and the sense of the fixedness of the world is wholly lost. Even in such an extreme case of intoxication, short of paralysis, the drunken man may see the world steady if only he can keep himself steady. I dare say we have all seen very drunken men walk quite straight, but with a preternatural fixedness of the head. If anything makes them

THE SPECTRUM TOP.

move their head, they totter and reel. They move the head a little; that happens to them in consequence of a small and slow rotation of the head which happens to us when we wag our head violently, and they reel and stagger just as we should reel and stagger if we tried to walk, violently wagging our heads all the time.

Just as there are blind men and deaf men, so there are men who have lost, or never had, the sense of rotation. Such persons are almost always deaf mutes. The close anatomical relation of the organ of hearing and the organ of the sense of rotation has this effect, that imperfect development or pathological injury of the one is usually associated with similar defect in the other; and experiments on deaf mutes have shown that a large proportion of them are defective in the sense of rotation. This is shown by the absence of the normal jerking of the eyeballs when they are rotated and by a perceptible insecurity in their gait. They do not reel as drunken men do, just as blind men find their way about much better than we could do if our eyes were bandaged; they have learned to get on fairly well with the help of experience and their other senses.

I am not sure whether, in this account of the sense of rotation, of its organ, and of the use of it, I have carried all my hearers with me and convinced you of the real existence and real practical use of this sense. I hope, however, I have made it clear that the subject is worthy of attention and that we have here matter for the careful consideration of physicists, physiologists, and psychologists.

THE SPECTRUM TOP.

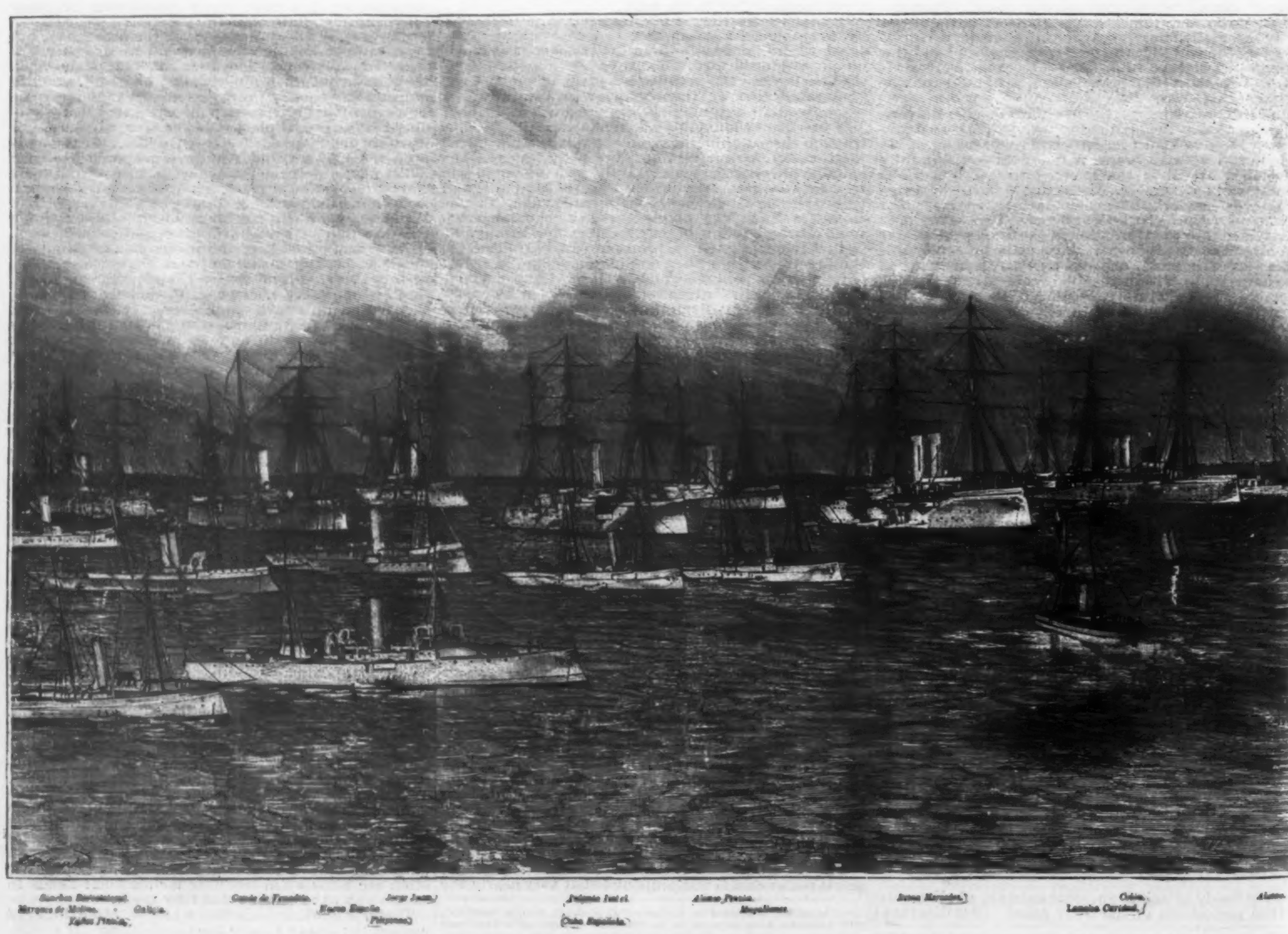
RECENT numbers of Nature have contained not fewer than eleven communications on "a spectrum top," and the instrument has been extensively discussed in La Nature, the SCIENTIFIC AMERICAN and other journals. Yet none of the writers seem to know that the phenomena were described by Fechner in 1838 (Poggendorff's Annalen), and were given a careful quantitative study and correct explanation by Rood in 1860 (Am. Journal of Science and Arts). They have also been discussed and illustrated by Brucke (Wiener Akad., 1864), by Aubert (Physiologie der Netzhaut, 1865), and by others. Indeed, Aristotle described the colored images following the exposure of the eye to white light. In view of these facts, it is somewhat amusing to find that Messrs. Newton & Co. write to Nature (March 14, 1895) that any one supplying the tops will be infringing their copyright.

The form used by Aubert is shown on the accompanying figure. If such a disk (best enlarged) be revolved 10 to 40 times per second colors will appear, varying with the rate of revolution, the intensity of the light, the observer, etc. Under favorable circumstances the colors may be of great brilliancy. They are undoubtedly subjective, being due to the fact that the components of white light vary in the time they require to call up a sensation, and in the time the sensation continues after the light has been withdrawn. But while we may refer these phenomena to inertia and fatigue, we are very far from having a satisfactory theory of all the facts of color vision.—Science.

THE WAR IN CUBA.

REAR Admiral Delgado Parejo, a most distinguished officer in the Spanish navy, has been appointed to the command of the Spanish fleet now in the waters of Cuba. La Ilustracion Española y Americana says that perhaps none of the honors conferred upon this officer are equal to that bestowed upon him by his selection as commander of the naval station at Havana, now that a war is going on in Cuba, the success of which particularly depends upon the navy.

In Cuba, as formerly on the American continent, and as happened in Flanders, in anterior times, and in the operations against the Moors in the kingdom of Granada, the rebels amounted to but little of themselves; they derived their principal force from exterior helps, without which they could not long have existed. It is necessary, therefore, for Spain to prevent the sending of aid to her enemies in Cuba; and the most efficacious means for doing this is to employ as many vessels as possible continually to watch the coast and prevent the approach of suspicious vessels. If only the disembarkment of men and munitions can



THE SPANISH FLEET IN CUBAN WATERS.

be prevented, the rebellion will dwindle away in a few months time.

Convinced of this, the government has sent to the waters of Cuba as many vessels as were found disposable, and proposes to send many more, taking advantage also of the merchant steamers, which will be able to render important help in this exigency.

Our engraving shows some of the vessels which have already been sent to Cuba. They are sixteen in number, of which six are cruisers, one torpedo boat, eight gun boats and one steam launch. Of all these vessels the largest and most powerful is La Reina Mercedes, of 3,000 tons. The new ships Colon, Infanta Isabel and the Conde de Venadito will soon follow. These vessels, together with some others that are already at the Havana station, others that are on the way thither and the armed merchant steamers, are what Spain has to intercept the foreigners who go to the aid of the rebels and who supply them with arms and munitions. Although this fleet appears sufficient for the purpose, in reality it is not, and very soon the government will augment the fleet still further; because the great length of the coasts of Cuba (more than 2,170 miles) facilitates the aims of the enemy, it being very difficult fully to guard so great a coast line. That it will in the end be well protected there can be no doubt; the government knows this to be the most efficacious means of bringing the war to a close.

THE CONDITION OF THE PARTHENON.

By SOMERS CLARKE.

EVEN those who have not seen the Parthenon feel an interest in the structure; a building which has always held its own as, perhaps, the greatest wonder of refined perfection among all the architectural wonders of the world; and, notwithstanding the grievous blows and buffetings it has undergone, its ruins still possess the most extraordinary power of fascination, partly through sheer majesty, beauty and refinement of form and partly from the charm of the material, the color, the situation and associations.

That this matchless building stands in imminent danger of ruin, even beyond that which has already befallen it, is but too evident.

Notwithstanding the explosion of the powder magazine within, which burst out the sides of the cella and overthrew the lateral colonnades, and notwithstanding the bombardments which the western front has undergone, still, from a distance, the building stands up and can be appreciated as a whole, owing chiefly to the fact that the western portico is standing, even including its angle cornices, and that the outline of the pediment is still preserved, although shorn, for the most part, of its cornice.

The fall of the angle cornices and their supports would be the entire and final ruin of the structure; a mere skeleton would remain, and it is at these angles that the greatest danger shows itself.

The construction of the building throughout being purely trabeated, there are in the original scheme no thrusts to counterbalance, no arches trying forever to overthrow their abutments. On the other hand, when stone beams are broken through, they have the trick of acting after the manner of arches, and may often be found to have sunk, until, while the crack gapes at the bottom, the two faces of the break are in violent pressure at the top, and the species of arch thus formed is only kept in its place by the resistance of the adjoining masonry—in fact, thrust is established, and that in a structure where the resistance to thrust forms no part of the original design.

The Pentelic marble, of which the Parthenon is built, was selected with the greatest care, any but the best blocks being rejected. The material is splendidly preserved, but after the lapse of more than 2,000 years, during which the marble has been exposed in the building, disintegration seems to be, in parts at least, making its way, and once begun, it may be making rapid progress, only perhaps to be made clear to us by the sudden collapse of an architrave under some unwonted although slight strain.

Since casts were taken, at the beginning of this century, of some sculptures still in their place, these sculptures have considerably disintegrated. What is going on with the sculptured surfaces is probably going on less manifestly in the great blocks of which the Parthenon is built.

The following notes, accompanied by rough sketches and by a reproduction of a photograph, will, it is hoped, make clear, to those acquainted with construction, in how great peril the temple stands.

The sketch diagrams are not to scale, and are only carried as far as is necessary to assist in explaining what has to be said. The beautiful and careful drawings published by Mr. Penrose, in his "Principles of Athenian Architecture," show, much better than I can do, the methods of construction adopted in the Parthenon. But for those who may not have the book at hand, the rough sketches, Figs. 1 and 2, may be of use.

By these it is seen that the architrave is built up of three large slabs, set on edge side by side, and having very ample support at the ends on the capitals of the columns. The vertical joints of these slabs are hollow. The slabs are only in contact for a few inches at the top and bottom, and there nothing can exceed the care with which the joints are made. These slabs are lettered A, A, A. Upon these slabs rest the triglyphs, B, B. The triglyphs are very large blocks, and rest partly on the outer and partly on the middle slabs, A, of the architrave.

The sides of the triglyph blocks are grooved to receive the slabs of which the metopes are formed. Behind these slabs are placed blocks of marble, which stand quite free. The purpose of these blocks was clearly to assist in carrying the great cornice stones, and at the same time to do this with much less material than would have been used had the work at this level been all in the solid. The weight on the architrave stones is, by this expedient, considerably reduced. Behind the blocks, B and C, is a continuous wall, E, which rests partly on the middle and chiefly on the inner architrave slabs, A, A. This wall carried the stone roof of the peristyle.

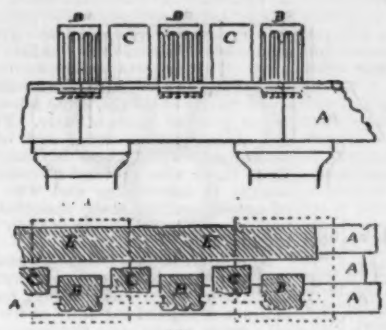


Fig. 1.

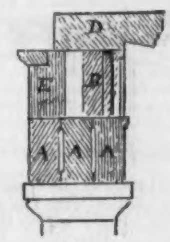


Fig. 2.

The section, Fig. 2, shows that where the cornice still remains the greatest weight is now on the outer stone of the architrave, and the tendency is to fall outward.

At the angles of the temple this outward tendency is very much increased. The triglyph is in these cases a huge solid block, larger and heavier than the triglyphs elsewhere; the cornice overhangs very far, and on its edge lies the sloping mass, at the start of the pediment cornice. As long as everything was in good order these great weights were no doubt counterpoised, but now, with the architraves more or less shattered, the pediments and the magnificent stones of the capitals broken, it seems only wonderful that the slightest earthquake shock does not overthrow the angles.

The sketches, Figs. 3, 4, 5 and 6, in conjunction with the photograph, show the excessive danger to which the slightest shock exposes the temple.

Fig. 3 shows the northwest angle of the west portico.

THE EAST FRONT OF THE PARTHENON.—FROM A RECENT PHOTOGRAPH IN THE BUILDER.

The outer stone of the architrave is cracked through; consequently the great block of the angle triglyph is standing on a very insecure base, and on this block rests the cornice. The abacus and part of the echinus of the angle capital are gone, while the capital of the next column southward is broken

The outward stone of the architrave has therefore a poor base. In its fall it would almost certainly heave up the work above it—indeed, the open joints of the

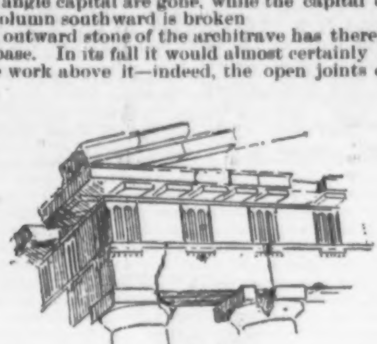


Fig. 3.

masonry at this angle show that there is a slight tendency outward.

Fig. 4 shows the capitals of the fourth and fifth columns of the western portico with the architraves resting upon them. The danger which threatens the outside architrave stones of the third, fourth and fifth inter-columniations cannot be overestimated. The capitals of the fourth and fifth columns have their face completely broken away. In consequence, nearly all the support of the outer slab of the architrave, except a very few inches, is gone.

The vertical joints of the architrave slabs are hopelessly shattered, and there is an ugly crack developing itself in the architrave of the middle inter-columniation. It seems that these stones are kept in their places solely by the weight of the triglyphs, etc., above tying them back, and by the wrought iron cramps with which nearly every block of masonry in the temple is tied to its neighbor.

The S.W. angle of the western portico is in equal danger with that at the N.W.

Fig. 5 shows the southeast angle of the east portico. Here we see the lamentable result of the fall of the cornice. The outline of the temple is entirely lost. The cracks and breaks in the masonry make it evident that, although the great mass of the angle cornice has fallen, there is still a considerable tendency to move outward.

The angle shown on Fig. 6 at the northeast corner of the east portico is perhaps in greater danger than is any other part of the peristyle. Here the abacus and part of the echinus of the capital are gone. The outer

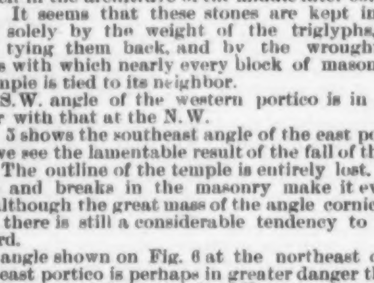


Fig. 4.

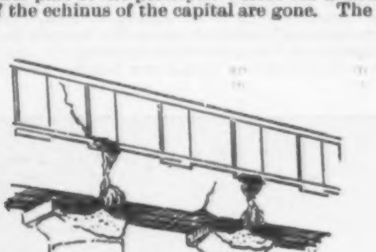


Fig. 5.

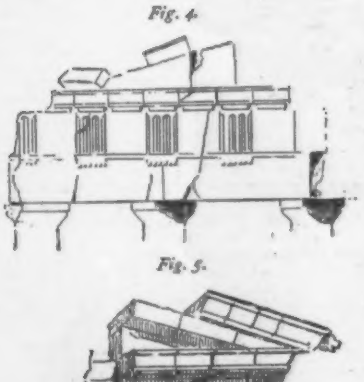


Fig. 6.

architrave stone is cracked in two places. Upon the outer piece which stands out in the air rests much of the great weight of the triglyph, and over this, much shattered, lie the cornice and the first stones of the pediment. As we look at it we only wonder why it does not fall at any moment.

Not only are the outer stones of the architrave broken as above stated, but many of those behind them are in a very precarious state. The insertion of new stones would be not only a thing difficult in itself, but one which would be most fatal to the marvelous effect of color the ruin now presents to us.

Pentelic marble is of a cold sugary white when fresh cut and takes very many years to mellow. It is beyond question that a great deal may be done with bronze tie rods, which would be almost, if not quite, invisible.

We cannot too strongly deprecate anything in the way of "restoration," and the insertion of new stones comes very near to this.—The Builder.

LIFE FROM A PHYSICAL STANDPOINT.*

By A. E. DOLBEAR.

I SUPPOSE there is no question about which science concerns itself and everybody has more interest in than this one of the nature of life. Some pretend to think we know nothing about it and never can know anything; others are quite as sure that we know it to be correlated with other forms of force and in some way convertible into them; while a third class may hold an agnostic position, content to wait until knowledge shall grow so as to include the nature of life. Still it may be doubted if there be any thoughtful person who does not hold some sort of a theory about it which he expects will be substantiated, and it is quite certain if any demonstration of the nature of life were to be given to-day there would be a great multitude of persons who would at once declare they had always so held. This expectancy shows itself in so many ways, that one may be sure that nearly every person has some theory of things, some scheme into which he contrives to fit all kinds of facts. That is to say, we can't get along without some sort of philosophy and we make our own if there be none otherwise provided. Even those who pretend to contemn all schematic attempts in knowledge and who mildly reprove such efforts by calling them speculations are easily found to have some pet scheme of their own which finds favor in their eyes.

Now there are speculations and speculations. There is a kind that has been common from the beginning until now, when imagination has full sway with no manner of regard for data or for appropriate facts at all. Such a one was the commonly held view as to the origin of the world and especially of living things, including man. They were created, at their beginning being the same substantially as we see them now to be. There is not and never has been in the history of man any phenomenon that could give warrant to such a hypothesis, yet it has been held and fought for by men now living.

Then there is another kind of speculation that has or tries to have proper data—that shows some respect for experience. Such was the attempt of Robert Chambers in the book called "Vestiges of Creation," a book which is deserving of more praise than I have yet seen awarded it, for he undertook to handle such data as were available to him, and he discerned dimly the process which all naturalists to-day see clearly. His data were inadequate and could not compel belief, but his attempt as compared with the hypothesis it contended against was as daylight to darkness. It had some experience in its favor; the other had none at all.

Lastly, there is a hypothesis derived from the study of groups of appropriate facts, the attempt to find an adequate explanation of all of them, without going beyond the bounds of possible experience, that is, without importing into the phenomena some transcendental conditions. Such is Darwin's Theory of Natural Selection, offered for acceptance as a provisional hypothesis thirty-five years ago. Also fought against stubbornly by naturalists, as well as theologians, in spite of the plain fact that it was either such a hypothesis or nothing; there was no other competing one that had any standing ground at all, which seems to imply that to some minds it is more rational to entertain an unintelligible hypothesis with no experimental data in its favor than it is to entertain one that has a considerable body of experimental data for its basis.

Swedenborg taught the nebular hypothesis, but gave no astronomical reasons. Kant developed it, giving philosophical reasons, which were not considered to be adequate. Laplace gave mechanical reasons which were adequate, and he who explains that theory to-day gives the reasons of both Kant and Laplace, but he quite ignores Swedenborg. Kepler explained the orbital movements of the planets as due to guiding spirits. Newton explained them by the doctrine of gravitation and dismissed the spirits from service. In his Principia he says he framed no hypotheses; nevertheless, he was a great framer of hypotheses, as, for instance, the corpuscular theory of light which he worked out, and his theory of a necessary ether which he did not work out. So hypotheses are absolutely needful for guidance in all profitable efforts, and as much so in science as anywhere else. Indeed, what is science if not our correlated experiences? It is interesting to see how men have tried to define it. Buckle says, "Science is a body of generalizations so irrefragably true, that though they may be covered by subsequent generalizations, can never be overthrown by them." Spencer says, "Science is a higher development of common knowledge." Others say, "Science is classified knowledge."

Our experiences of all sorts are the subject matter of science, our interpretation of them is our attempt to be logical, our attempt to be scientific, and a true interpretation of any phenomenon will not be inconsistent with any other truth, that is, it will be consistent with all we know and all we can know, so that any hypothesis that is plainly incompatible with the best we know has no place in science.

So much to clear the way for a proper consideration of life from a scientific standpoint. Some sort of a theory of it is needful for giving direction to research, for if it be a proper subject for investigation, the implication is that its explanation will be found to be consistent with what else we know, and it be not a proper subject, then research is a waste of time. If one assumes that life is some sort of transcendental thing or property not necessarily related to the other things and properties we describe and explain, such a one sets bounds to knowledge on the basis of what he does not know. If, on the other hand, he is to correlate it with other knowledge, his induction must be wide enough to include all phenomena into which life enters in any degree.

The old theory of a vital force did the former. It assumed that there was in a living thing some sort of an entity capable of directing the functions, and that the physical and chemical conditions present were subject to its domination. It made the distinction between a living and a dead thing to consist in the presence of a force radically different from all other forces, which presided for the time in much the same way as Kepler's guiding spirits presided over planetary motions.

We know what the history of such prepossessions has been. A hundred years ago caloric was thought to be such an imponderable potency, light was thought to be another, electricity still a third. Each of these turned out to be no imponderable at all, but simply physical properties of matter of the ordinary sort. But the change from the old to the new view in these matters made it needful to change the fundamental ideas concerning matter itself.

The physiologists for a generation have ceased to think of a vital force as different from other forces in the same way as they have ceased to consider light as an emanation. And the consensus of opinion among biologists, if one may judge from a multitude of expressions by them concerning life, is that all the phenomena exhibited by a living thing are finally resolvable into physical and chemical processes.

A vital element peculiar to organisms no more exists than does a vital force working independently of natural and material processes.—Claus and Sedgwick.

It must not be supposed that the differences between living and not living matter are such as to justify the assumption that the forces at work in the one are different from those to be met with in the other.—Huxley.

Zoology, the science which seeks to arrange and discuss the phenomena of animal life and form as the outcome of the operations of the laws of physics and chemistry.—Lankaster.

Certain it is that life is a chemical function, says Prof. Stokois, of Amsterdam, and he adds, Is not the chemical function a sort of life?

So vital force, as a distinct somewhat invented to account for living phenomena, has now no status anywhere. If it be so, then it is plain that matter has properties which have not been included in its list. If matter has been defined as inert, or as dead or as inanimate, one may have to revise his definition. Is it not plain in an à priori way that the phenomena exhibited by living things are to be explained only on the assumptions, first as due to the inherent properties of the matter that exhibits it, or to some external agency—not inherent in it, to which the name vital force is just as good as any? and if this has been discarded for seemingly good reason, then there is the other alternative only. But somehow most men who have thought about it have felt loath to adopt this. Is not this the same as saying that there is somehow felt to be a good reason for refusing to adopt it, even in the absence of any proof that it is untrue? I suspect it lies in the common unanalyzed notion into which we have all been schooled, that matter is dead and inert and out of it can come nothing but so-called inorganic phenomena. Along with this has come a relatively new piece of knowledge called the conservation of energy, which asserts that all the forms of energy are transformable and that the sum of their energies is a constant quantity. None hitherto being able to see how vital and physical phenomena are correlated, men have been loath to believe it to be a fact—a mental position which assumes that before a relation can be logically accepted it must be explained, which is not true. The relation between mechanical energy and electrical energy is very definitely known, yet it has not been explained; but in this question there is no personal equation, no such lively interest in its settlement as in the other. The one has only mechanical interests involved, the other is so much of a sociological question as to threaten war involving church and state. Dr. Barnard, a former president of Columbia College, said concerning a certain debatable statement in science, that if it were true he did not want to know it, and that is the way a large number of persons feel about this question of life in its relation to ordinary matter.

As every one knows, our knowledge of matter has wonderfully increased during the past twenty-five years, and along with this knowledge has come to the conviction that the older conceptions of its nature and its possibilities cannot possibly be true. It becomes important in a matter of the kind under consideration that one should know what he is entitled to postulate concerning matter, and this for the manifest reason that every living thing in our experience consists of a mass of ordinary matter, and we have no experience of any living thing not so embodied. From mammoth to monad there are the same elements combined. Evidences of life are of various sorts, but generally they consist in movements of some kind, which may be locomotive, or such as involve maintenance of functions of nutrition, temperature, and so on in animals; but in plants of the higher types there is apparently only maintenance of nutrition and reproductive functions. In seeds and eggs, there is somehow the presence of life without any of the obvious evidences. Take a hen's egg for instance. Is it alive, or shall we ask, Is it capable of living? Two very different questions. If it be kept at a temperature of 104° for three weeks, the most wonderful transformation takes place, and out of the albuminous mass has grown a thing with curiously adapted organs and endowed with intelligence so it can take care of itself. If, on the other hand, the same egg had been heated to 150° for five minutes, or cooled to 32°, all possibility of growth would have been stopped. What difference can temperature have on life?

What is temperature? Physically it is atomic vibration and is measured by its amplitude. How does atomic vibration affect the conditions of matter? It permits different combinations at different degrees, so one would infer that the egg molecules were chemically disrupted by considerable changes in temperature. But if the egg had other qualities not physico-chemical in nature or necessarily related to them, what becomes of them when there is a change of temperature? Put the same egg away for two or three months, and then it is found to be as unable to grow into a chick as if it had been boiled. What now has taken place—chemical disorganization as before. A grain of corn can stand a much wider range of temperature, and maintain its ability to grow under appropriate conditions of warmth and moisture, and this too for a much longer time, some years; but it slowly deteriorates and in a few years with the best of care it loses—what? its life? Does it really have

* Biological lectures delivered at the Marine Biological Laboratory of Wood's Holl in the summer session of 1894.

life until it begins to grow? Let that process once begin, and it cannot be arrested. It must continue to go on or it will disintegrate at once. When the proper temperature has once tumbled over the statically arranged molecules of the egg, proper energy for continuing the process must be furnished or the whole structure comes tumbling down and then we say the thing is dead. One may say that heat or temperature did it, but it is better for clearness of vision to see that these terms mean only a kind and rate of motion and nothing else, and then one can understand better how molecular stability depends upon temperature, whether in an egg or in water. Hence, in some way life is an affair of atoms and molecules rather than of large and visible masses of them.

How large are the smallest masses that exhibit to the biologist the phenomena of life? Each increase in magnifying power has presented to him still smaller masses having this quality. If one can now see living particles the hundred-thousandth of an inch in diameter, is there any reason for supposing that such a particle is the smallest really living thing? Certainly not. Well, then, how much finer may matter itself be divided? There is reason for believing that the atoms of matter such as hydrogen, oxygen, and carbon are approximately the fifty-millionth of an inch in diameter, and a mass of matter the hundred-thousandth of an inch in dameter would contain 125,000,000 such atoms. Would one think there would be any probability in the proposition that the smallest living thing must contain that number of atoms? If not, then what has the miscroscope got to say as to what has been called spontaneous generation? There might be millions of living things too small to be seen, having any number of qualities, such as growth, assimilation, reproduction, and so on, and this smallest thing we see be only the last in a long succession of growths and developments. Again, if life be not a miraculous endowment, would any one think there could be any probableness in the proposition that the number of molecules and their arrangement merely determines the presence or absence of life? Does the number and arrangement of molecules determine whether there shall be gravitation, or elasticity, or temperature among them?

Observation shows no limit to the size of a mass of matter that exhibits the quality called life, and philosophically there is no reason for setting any limit to the size, as one might as well start with a mass the fifty-millionth of an inch in size as with one the hundred-thousandth of an inch. In the absence of any evidence of there being some sort of a physical and chemical hiatus between those limits one is not at liberty even to assume that there is, and if some of the phenomena that come out from aggregates of molecules he is not able to explain satisfactorily, it is safer to enlarge the possible attributes of atoms themselves than to summon a genie who is wholly unaccountable when off duty. But the whole theory of matter was that it was absolutely powerless in itself, and that the so-called forces of heat, light, electricity, chemical affinity, and so on by themselves could bring nothing but disorder, and that arrangements and adaptations required other than such agencies to establish. That this is not so may easily be shown.

Here is the solar system, an orderly body of rotating and revolving globes, the orderly arrangement and motions of which are believed by all astronomers to be due solely to mechanical agencies, gravitation, and the laws of motion. Look at a snowflake, how beautifully symmetrical in its hexagonal geometry! A difference in temperature of less than one degree determines whether it shall remain a crystal or shall lose its embodiment of form and become a minute drop of water. Here again we meet with temperature—that is vibratory motion as determining not only whether a mass of matter shall exist as a solid or as a fluid, but that it shall exist in a symmetrical form, and not as a hodgepodge of molecules. It is proper to inquire if, in order to produce such an orderly arrangement of molecules, it is needful to imagine some extra-physical agency in order to account for it. I suppose no one assumes that now, even if he has no conception how the phenomenon can be due to merely physical agency. Such a one has enlarged his concept of the possibilities of matter and is not therefore surprised at the evidences of organizations of that kind. A hundred varieties of stars, or plumes, or feathers, or fern forms are attributed to the properties of molecules without other help. He may not trouble himself to find an explanation, but if he does concern himself to find a mechanical explanation, he needs to know more about atoms and molecules that he may perceive how certain kinds of motions necessitate orderly arrangement.

That the atoms of matter have internal vibratory movements is proved, 1st, by their elasticity in the gaseous form; 2d, by the uniformity of the wave length of light when made incandescent, as shown in the spectrum of a gas, indicating as plainly as can be that the atoms have their regular rates of vibration, an enormous number per second. As the velocity of light is 186,000 miles per second, a wave length the fifty-thousandth of an inch long implies that atoms that produced it vibrated as many times a second as the fifty-thousandth of an inch is contained in 186,000 miles, something like 600 millions of millions. If one cannot conceive such a number, he is compelled by his arithmetic to believe it represents the truth. But the thing of importance here is to picture to one's self the vibratory motion itself, and here one must have recourse to mechanical models. It may be well to remark that the idea of hard, round or spherical atoms has been abandoned by physicists as having no probability at all, but whether atoms have one form or another, they certainly have these vibratory rates, and one may make his mechanical models in any way that shall not be incompatible with such physical properties as atoms are known to possess.

Within the past 20 years the evidence has been fast accumulating which gives credence to what is known as the vortex ring as being the form of the ultimate atom. The puff of smoke and steam from a locomotive which goes sailing as a ring high in the air, wriggling, vibrating and twisting constantly, but maintaining its ring shape in spite of these, is an example. Such a ring has form, elasticity, momentum, energy and other physical properties. So if one considers what vibration in such a ring consists in he will have a fair conception of it in an atom. Its diameter lengthens in one direction until its shape is elliptical, a b (Fig. 1), then it swings back into an ellipse at right angles to the first, c d, and the rate at which this will take place depends upon the size and the degree of rigidity which the ring has. Such vibratory motions constitute the temperature energy of the atom. But it is to be noted that with such kind of motion there are parts of the ring which have a maximum amount of motion and other parts with minimum as at n. Suppose, then, that for any reason such atoms should attract each other, say gravitatively, and come together, is it not evident that they could adhere to each other only in certain places, the so-called nodes, n, of which there are four when the vibrations are of this simplest type? So each such atom would have four points upon its circumference where there could be adhesions. This is the same as saying that so long as such an atom has any temperature its possibilities of combination will be limited to the conditions of its

FIG. 1.

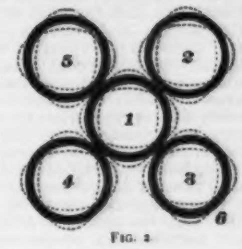


FIG. 2

vibratory rate, and this will be definite at a given temperature. Such definite combination we call chemical combination, and the combination itself a molecule.

Follow out the possibilities of structure with such conditions and one can see how cubes and hexagons result from the positions of the nodes of vibrating bodies, and thus orderly arrangements, as exhibited in crystalline forms, follow, from a simple mechanical process.

Thus consider the rings in the diagram (Fig. 2). The ring, 2, touches upon 1 at the node or place of least vibration, and likewise its own nodes correspond in position with those of 1. In like manner rings 3, 4 and 5 are similarly placed, and each individual of the combination could vibrate symmetrically without disturbing its neighbors. This would also leave each one free to swing as upon a hinge upon 1. Imagine, then, that 5 and 3 should swing upward from the plane of the page and lean over until they touched over 1. It is plain to see that their nodes would then come together and their individual vibratory rates would in no way be interfered with. If the whole should be turned about so as to be looked at edgewise, it would look like a triangular arrangement (Fig. 3), and half a

FIG. 3

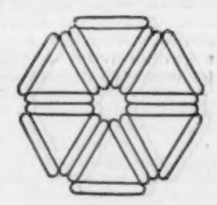


FIG. 4

dozen such would fit together to form a hexagon (Fig. 4), a form of crystallization very common; for example: water, H_2O; silicon, SiO_2. Again, assume that 2, 3, 4 and 5 should each swing upward together until their edges touch; they would then form the sides of a cubical box, and, as in the other case, their nodes would be opposite each other, and there would be no interference of vibratory motions. Similar cubes could be added on every side, and a cubic structure built up of any size if the individual rings were of the same size. If some of them were of different size, the resulting structure would have some angle of inclination of its sides which would be uniform if the individual parts were similar. If such triangular, cubical or other elementary form be a stable one, as evidently it would be mechanically, one might call it a molecule, but its form would be seen to depend upon its vibratory motions, and if this constituted the temperature of the body, then it would be clear how molecular form depends upon heat.

Suppose now the amplitude of such motions were to increase, the stability of the combination would necessarily grow less and less until it would be mechanically impossible for any two atoms to remain together. Such increase in amplitude means increase in temperature, and such breaking up of chemical combination by heat is called dissociation. This kind of a process with only details varied in a mechanical way gives an intelligible account of the actions called chemical, and they are in complete accord with that new science which has been developed within the past few years, and is known as thermo-dynamics. Investigations of many sorts have led physicists and chemists to the conclusion that at absolute zero chemical action cannot take place. Indeed, long before that temperature is reached, substances that energetically combine at ordinary temperatures lose all semblance of affinities and cannot be made to unite. Now the point of this chemical disquisition is to make it plain that orderly arrangement and phenomena follow from orderly motions, and one has no need for inventing other agencies when the latter are known to be present, as is true in this case. One may safely postulate that ordinary matter possesses such inherent qualities as enable it to assume geometric forms that depend upon temperature.

But the matter we know possesses other qualities that have to be reckoned with. First it possesses energy even when it is seemingly quiescent. For example, when carbon, sulphur and saltpeter are mechanically mixed together, as one might mix sand and salt, we have a mixture that possesses a relatively large amount of energy, which we have not put into it. The mixture simply makes the energy available. A lump of coal might lie around and seem to be as helpless and inert as any stone, but we drive our steam engines with its like and heat our houses, and civilization depends upon it to-day because it is loaded with energy which a furnace makes available. The energy is in it, and if it is not apparent under ordinary circumstances it is evidently not correct to speak of it and reason about it as if it were really inert and dead. One might liken it to a sleeping rather than to a dead man.

What is called the dynamic theory of matter is an implied denial of inert matter.

A pound of hydrogen and eight pounds of oxygen contain energy enough to wreck a large building. In like manner the substances used for foods are loaded with energy in a shape available for use in living structures; so one has no need to assume some external source of energy for the purposes of any living thing, but this energy resides in the atoms, for molecules are but aggregates of atoms, and there is nothing in molecules which was not before in their constituents. This energy is not all of it, nor any considerable part of it, due to their temperature; that is, it is not to be measured by the temperature, for it is evident that such a structure as I have described is itself an embodiment of energy, for it consists in a rotary movement of something, at an extremely rapid rate. When a mass of matter is heated and left in space it presently cools by a process called radiation, that is, waves in the ether are produced by the vibratory motions, and the energy is handed over to the ether, which carries it away at an enormous velocity, that of light, but the kind of energy which itself represents it cannot yield up, yet it reacts upon this same ether in another way so as to reduce the pressure about itself; so one might very well consider that half of the energy of the atoms lies in the ether and is exchangeable with it, that is, the atom can apparently call in a supply of energy, from space, for an emergency.

The space about a body, within which it is capable of affecting other bodies without contact with them, is called its field, and there are several different kinds of fields. The gravitation field is as extensive as space, for every particle of matter attracts every other particle, no matter what the distance. In like manner every heated body sends out its radiant energy to other bodies to an indefinite distance, and the bodies on which such radiant energy falls are heated like the first. An electrified body has an electric field, within which other bodies become electrified simply by being present in the space. A magnet has a magnetic field, and iron and some other bodies become sensibly magnetic by being in such magnetic field. Likewise atoms have chemical fields, within which chemical reactions of definite sorts are induced. This field has in some instances been traced in solutions nearly an inch from the body producing it. The effect of this field is similar to that of the others, namely, to bring about chemical reactions, and therefore molecularly organized products similar to that of the originating body. A minute crystal of a substance will cause the crystallization of a large mass of the same substance in solution. So that here are other attributes of atoms, in which their conditions and motions bring about similar conditions and motions in distant bodies, by what is called sympathetic action, just as a vibrating tuning fork will set another tuning fork vibrating, if the latter has the same pitch, though it be many feet away from the first.

Does it not appear that matter has greater and more wonderful endowments than has been supposed? loaded with energy, acting sympathetically at a distance upon other bodies and organizing itself into symmetrical forms, through simply mechanical action.

Most of our knowledge of matter and its properties has been derived from study within the past thirty or forty years, and there is no reason for assuming that all are known and appreciated. In every direction, almost, there is good reason for thinking that much will be added, but it is certain that enough is known to quite debar any one at present from dogmatically limiting it. We do not know enough about it to limit it, and what we do know gives no warrant for limits of any sort.

In all this one might well say that such phenomena as you have described might fairly well be true of inorganic matter or what has been held to be non-living nature, and yet leave the peculiar phenomena of living organic matter yet to be explained. And what are the peculiar phenomena that belong to the living thing and not to the non-living? Are they the phenomena of spontaneous movement from place to place? Hardly that. Rub up some gamboge in water and examine the particles in the microscope, and they are seen to be in constant movement like animalcules, and this they keep up. Scatter a few bits of camphor upon water and watch the movements. Each particle swims around upon the surface with surprising velocity, and each one carefully avoids collision with others as if it were alive, and this is kept up until the camphor is dissolved or evaporated. A drop of creosote upon a water surface behaves in an equally surprising manner, as do most of the so-called essential oils, each one having some characteristic movements which enable one to identify it by its behavior on a water surface. Some of these are explained as due to evaporation, cohesion or surface tension, and others to molecular exchanges of energy between the particles and the medium, but these names signify molecular properties and show that it is possible for molecular energy to show itself by just such kinds of movements as living things exhibit.

Hofmeister, of Prague, has shown to a demonstration that all which has hitherto been considered the elective affinity of the living cell can be explained in the most natural manner in the world by its colloid condition and chemical constitution.

Within the past few years several experimenters have been studying the characteristic movements that take place in emulsions of soap, oils, and so on, with the result as announced, that they are substantially the same as those seen in amœbiform masses. Pseudopodia are formed, an absorptive material in the neighborhood is gathered in, a duplication of the process of feeding and of digestion. Such material has been called artificial protoplasm, and a short account of it will be of interest to those who have not chanced to meet with it.

Professors Quincke and Butschli, of Heidelberg, have perhaps done more in this line than any others, and the latter has published a monograph of 280 pages

quarto, with six plates, on such artificial protoplasm. Quincke found that, if a substance soluble in water be finely powdered and rubbed up with oil and then surrounded with water, the water diffuses into the oil and makes of it a kind of foam, consisting of minute drops of water closely packed together in oil, and thus presents the appearance of honeycomb structure.

The soluble substance which works best for this preparation is K_2CO_3. Olein oil is generally used—ordinary oil is useless—and much pains need be taken in preparing it, but when a minute drop of this properly prepared substance is placed in water or a mixture of equal parts of glycerine and water, it becomes clear and transparent and exhibits changes in shape; streaming movements like those of an amœba are seen, which are kept up for hours. It throws out processes and withdraws others, and the drop as a whole will change its position.

Up the center of the processes there is a streaming movement to the end of the process, where it spreads out and flows back in a layer next the surface. The movements are influenced by warmth and by electricity, and one who did not know what it was he was looking at would suppose he was seeing an actual amœba.

Frommann, Klein and many histologists find that protoplasm consists of a kind of network of less fluid material, the interstices being filled with more fluid material. Indeed, such kind of structure is thought to be true of every kind of animal cell.

This view is an advance from the older view that protoplasm was wholly structureless and homogeneous. Butschli, however, on the basis of his experiments and observations, concludes that protoplasm is an emulsion of two fluids, which mechanically presents the honeycomb structure, and that so far the structure is wholly due to the physical and molecular qualities of the substances which exhibit it, and that what was taken to be a network peculiar to a living mass is really only emulsion. He finds it too from protozoa to vertebrate. The interfibular substance of muscle which has been taken for network by some observers, Butschli finds a honeycomb with transverse partitions, and the fibrated axis cylinder of a nerve has cross strands, indicating this also to be honeycomb. As there are many degrees of fineness possible to such physical structure, it would follow that if there be so-called "structureless" protoplasm, it is only apparently so, because the meshes are too fine to be seen.

The honeycomb structure is believed to be an albumen containing some molecules of a fatty acid not miscible with water; the more fluid parts which fill the interstices are watery fluid containing albumen and alkali. Such chemical substances in such close physical relations would necessarily permit such phenomena of movement as are seen in such microscopic masses of living matter. The shorthand explanation is that these are due to surface tension and chemical actions; so both structure and motions are thus reducible to purely physical and chemical terms. The success that has attended the efforts of chemists in synthetic chemistry has emboldened some of them to assert with confidence their belief that every kind of a combination can be artificially produced, and that when the substance protoplasm is formed it will possess all the qualities of protoplasm, including life.

Now albumen, $C_{219}H_{338}N_{52}O_{66}S_2$, is very closely related to protoplasm and some kinds seem to be nothing else. Egg albumen contains 1 sulphur atom for every 70 of carbon, globulin albumen 146 and hæmoglobin albumen 350, or ratios of 1, 2 and 5—a rather striking fact.

Already albuminoid bodies have been artificially made, but they showed no vital qualities. If Butschli's experiments signify anything, they signify that nothing of the sort should be expected from a substance chemically homogeneous like precipitated albumen, for there are required two differently constituted substances, physically mixed, not chemically combined, and no mere chemical process or chemical product could give such a mixture.

It is evident that in a chemically homogeneous mass there can be no occasion for changes of any kind within it, and chemistry alone cannot give us any substance which can give characteristic vital actions.

It is true enough that the materials with which Butschli has made his observations are not the same as the real substance of living protoplasm, yet they are not so far apart as one at first thought might imagine. Whenever chemical action is taking place, whether fast or slow, these exchanges in the form of energy are likewise taking place, changes from molecular to mechanical motions, from one degree of absorption and conduction of heat to another, from one degree of condensation to another, and so on, and now let one add to these the quality of atoms, referred to a little way back, namely, that their field of action is not limited to a push or pull by contact, but that it acts at a distance from itself in various ways, and one of these is to compel other masses in its neighborhood to assume the same form and condition as itself—that is, the so-called sympathetic action. It can be apprehended that when there is energy being expended in this kind of a way we have a process which is called growth.

If the molecules are closely adhesive, as they are in so-called solids, the growth can take place only upon the outer surface, yet even here the growth is limited to the same kind of material as that of the initiating mass; that is to say, a crystal of salt will only annex salt molecules to itself, so, though there be several different substances in a solution capable of crystallizing, each one will select molecules of its own kind, and each crystal is similar in kind and structure throughout. This is a kind of natural selection inherent in the atoms themselves.

But there is the widest difference in character between the few elements that make up a living thing, from oxygen with communistic instincts to nitrogen with antisocial qualities and strong individual proclivities. If induced or compelled to associate with other elements, it is ready on the slightest provocation to abandon them and become a free rover. Gunpowder, nitroglycerine and the fulminates are examples of the qualities of this element to effect disorganization. This element is always one of the constituents of protoplasm, and one might therefore expect it to be unstable and restless, as indeed it is.

One of the indications of the rate of activity of any kind in an animal is the rate of elimination of nitrogen. This is emphasized here in order to make it plain first that the origin of movement in a living thing is to be traced to the energy embodied in the chemical combinations, and second, that particular movements, or at any rate some of them, which have been attributed to some directing agency—vital force, or life—are due likewise to harmonic changes of energy inseparable from the atoms themselves.

Movements that result in change of position of the body are called mechanical; movements that result in the enlargement of the body in one way or another are called growth; movements that result in the organization of another similar body are called reproduction—and the similarity of the second to the first has been attributed to heredity, a term expressive of a fact, but embodying no explanation. The conditions in the neighborhood of such growing thing, that react upon it in one way or another, are called its environment; and this, too, has been a hazy term, as applicable to one thing as to another; but in this particular field internal changes necessitate external changes beyond the boundary of the changing body, so as to modify the possible reactions upon it, and in every case it represents but the transformations of energy in exchange from one kind and amount to another. Here, as elsewhere, Providence is on the side of the heaviest artillery, and more energy of any given kind always dominates the less.

When a young duckling waddles into the water the first time the action is attributed to instinct. When the terminal of a rootlet leads off in the direction of moisture and nutriment, is it not instinctive too?

In each of the hypotheses devised to account for the phenomena of heredity, from Darwin's Pannixia to Weismann's somatic and ideoplasmic cells, there is an effort to look for the basis of heredity in some peculiar form or composition of matter, which possesses qualities unlike the other kinds of matter with which it is associated. From the physical standpoint one must go farther back than any combination to find the meaning of any combination. If one has abandoned vital force or some equivalent for it, and agrees to rely upon physics and chemistry as his antecedents, there is no good reason why he should expect to get out of a hundred molecules what is not in the individual molecules to begin with. Otherwise he is expecting to get out of his mechanism what is not in it.

But here, so far as the affair is a physical and chemical one, the causes and the conditions of such changes as take place in living organisms are altogether molecular and atomic, and no one has yet seen how to endow a molecule with qualities it does not originally possess; and, so far as present knowledge goes, the way to modify the qualities of a mass of matter is to change its atomic constitution, either in number or arrangement, or both. Each new combination has its peculiar characteristics, because the field of any kind of a molecule is the sum of the overlapping fields of its atoms. As the field determines the arrangement of other matter within it, it is plain that any new combination—that is, one having a new atom in it, or an old one displaced in even an accidental way—would build up other molecules like itself out of adjacent unorganized materials, and, as older organizations are necessarily more stable, later atomic acquisitions must be easier lost or sloughed off, and so there would be what is called reversion to earlier type, yet still accounted for on purely physical principles.

As biologists have been able to trace so-called vitality to the smallest particles which can be seen, and have found that no special form of matter is essential as a habitat for it, so physicists have been able in so-called inorganic matter to trace similar characteristics, and so approach the subject from another side. The mineralogists themselves are asking now the question whether the evidence at hand does not warrant the conclusion that matter itself is alive. That can only mean that life is to be considered as an attribute of matter in the same sense as is gravitation or elasticity. To take it there is to go behind even Butschli's work and conclusions, for such evidently assume that life as manifested in such masses as have been studied is a resultant of the physical and chemical action present in the mass, while the other view sees in such structures degrees of complexity depending simply upon complexity of combinations, and that the beginnings of it are to be looked for nowhere else but in the atoms of matter themselves, which view, by the way, would settle the question of what is called spontaneous generation, for matter has always been alive, and wherever there is matter there is life, that is, ability to combine, to grow, to reproduce, and these processes go on whenever the environment is suitable for it. With such kind of matter there is neather creation nor destruction of life, only changes in the degree of complexity of it.

But I have before remarked on the fast-accumulating evidence that atoms of matter are vortex rings of ether in the ether, and I would here again like to emphasize this statement, not that it has been proved beyond a peradventure, but first, because there is no other theory at all; and, second, because there is much in favor of it and little or nothing serious against it. I take it that some of you are already adjusting your ideas to such a contingency as is indicated by Dr. Ryder's paper here last summer. He was making vortex rings out of vortex rings, but the ones I mean are fundamental. Now the motions which constitute a vortex ring are known, and some of the qualities that flow from such motions are known. In a frictionless medium, like the ether, they are persistent, indestructible existences, abiding through all changes, and apparently never changing their physical qualities. The hydrogen that has been combined in rock laid millions of years ago has the same qualities as that derived this instant from disintegrated water; but, whatever those properties are, they are derived from the ether itself by some process we are in absolute ignorance of. It will not do to call ether matter, meaning by it what we mean when we speak of oxygen or carbon, for there is no evidence that such qualities as gravitation or magnetism belong to it. And if matter be such a form of motion, then the ether must have existed before the atom did, and, as no known form of energy is capable of setting up such a motion in a frictionless medium, it also follows that all this implies some other kind of energy in the universe, different from any in our circle of related energies and outside of them—yea, not necessarily related to them as they are to each other; for first, the properties of the ether itself are not to be described by the terms appropriate to matter, and, second, matter is a form of energy, and is, therefore, itself a product of which the ether itself is but one of the factors; so what else may be involved in it one cannot say further than that something else must be, and I think this "must" may be written large, even though it quite transcends our ability to make out any of its characteristics. At any rate, it is evident that if any such theory of matter as is here presented be true, and if the behavior of matter as we see it in test tube and microscopic slide has been interpreted with any approach to the truth, then it is a much more wonderful thing than the old philosophers thought. Its possibilities greatly exceed what could before have been imagined, and if mind itself requires a material habitat, then it has in an atom an imperishable living home.

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PUBLISHED WEEKLY.

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